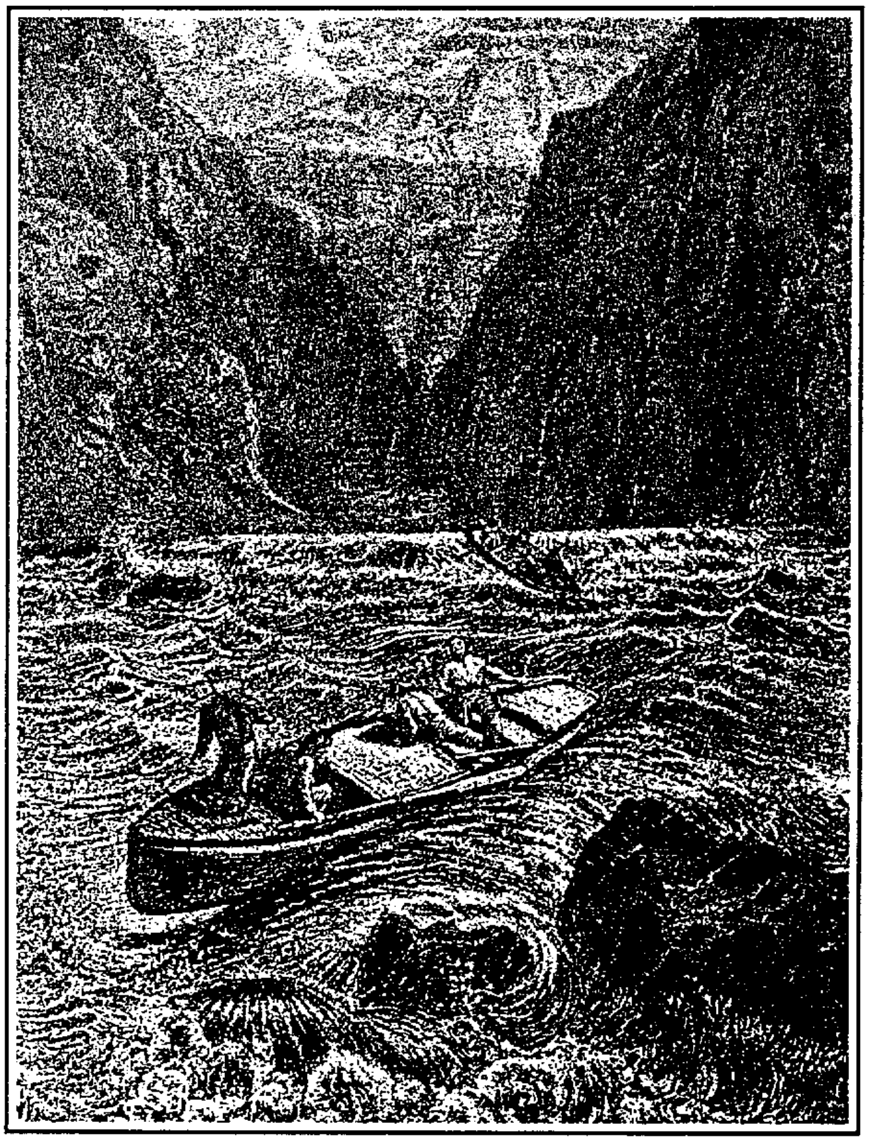
Life History and Ecology of the Humpback Chub (Gila cypha) in the Colorado River, Grand Canyon, Arizona

Supplement No. II:
Evaluation of Sampling Design



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Life History and Ecology of the Humpback Chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona

Supplement No. II
Evaluation of Sampling Design

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EVALUATION OF SAMPLING DESIGN

INTRODUCTION

This report is an evaluation of the sampling design used by BIO/WEST, Inc. (B/W) to investigate the fishes of the Colorado River in Grand Canyon. This report is one of six supplements to the Final Report entitled Life History And Ecology Of The Humpback Chub (Gila cypha) In The Colorado River, Grand Canyon, Arizona. The Final Report describes work conducted under Bureau of Reclamation Contract No. 0-CS-40-09110 to evaluate the effects of Glen Canyon Dam on the humpback chub.

This report evaluates the effectiveness of sampling methodology including a description of sampling effort, sampling gear efficiency, catch by gear type, and an evaluation of marking techniques. The report also assesses injury to the fish that were handled during the investigation by evaluating handling methods, capture methods, marking methods, radiotelemetry, and stomach pumping. Conclusions and recommendations are presented and discussed to provide suggestions and guidance for future researchers in Grand Canyon.

The methods evaluated in this report are described in a companion document, Supplement No. I: Data Collection Plan (Valdez and Trinca 1995), issued as a supplement to the Final Report.

The tables and figures for this report are located after the text. Some tables and figures were too lengthy or cumbersome to include within the text or sequentially where they were cited

EFFECTIVENESS OF SAMPLING METHODOLOGY

This chapter evaluates the effectiveness of methodologies used to sample fish in the Colorado River in Grand Canyon. Understanding the efficacy of sampling methods is vital to understanding the extent and applicability of data collected. The information revealed from these evaluations was used to guide data partitioning and analyses.

Distribution of Sampling Effort

Sampling was conducted according to spatial and temporal stratification in order to distribute effort as evenly and comprehensively as possible. While the sampling design was defined according to these criteria, actual sampling effort was sometimes affected by river conditions, weather, logistics, equipment malfunctions, or safety considerations.

Spatial Stratification

The Colorado River from Lees Ferry (RM 0) to Diamond Creek (RM 226) was divided into four regions (0, I, II, and III), according to general longitudinal characteristics of biological production, water quality, and fish distributions, as well as tributary inflows (Fig. 1). The river was further divided into 11 geomorphic reaches described by Schmidt and Graf (1990). Longitudinal sampling strata were established within each geomorphic reach as the basic sampling units and as representative areas of respective reaches.

Region 0 (RM 1-56) received substantially less sampling effort with all gear types because it was sampled only during 11 of 36 months of the investigation (Fig. 2). Although sampling was designed for approximately equal effort in Regions I, II, and III, none of the primary gear types met the criteria of the design. Most of the netting and electrofishing effort was expended in Regions I and II (73%

and 76% combined, respectively), and most of the trap and seine effort was expended in Region I (79% and 63%, respectively).

Failure to comply with this aspect of the sampling design restricted certain data analyses and inferences to longitudinal distribution and abundance of fishes. Distribution of sampling effort by region was attributed primarily to constraints in use of specific gears with river conditions (e.g., Region II was dominated by deep, swift shoreline currents that precluded seining), and use of gears to meet specific objectives (e.g., minnow traps were used primarily in Region I to evaluate abundance and movement of young humpback chub). The high level of sampling effort and the relative effort expended by region attest to the magnitude of sampling necessary to thoroughly characterize of the Grand Canyon ichthyofauna.

Although sampling intensity with specific gear types was not uniformly distributed throughout the four sample regions, incidence of sampling--as indicated by number of times an area was visited--showed that all sample strata were visited on at least one-third of all trips, except for those in Region 0. Each of the 11 sample strata in Region 0 was sampled at least twice, except for RM 35.9 - 43.7, which was sampled only once (Fig. 3). RM 26.5 - 35.9 was visited nine times to assess the size and distribution of a local aggregation of humpback chub (i.e., 30-Mile aggregation). Each of the four sample strata in Region I was visited at least nine times--RM 56.0 - 61.5 and RM 61.5 - 65.5 (LCR inflow) were each sampled 33 times (every trip). Sampling within Regions II and III was relatively evenly distributed, with a focus on inflows of major tributaries (e.g., Shinumo Creek within RM 107.8 - 109.8). Each of 13 strata in Region II was sampled at least four times, and each of seven strata in Region III was sampled at least seven times. Specific information on longitudinal sampling effort of the two primary sampling gear types, nets and electrofishing, is presented below.

Nets. The percentages of 1-mile sections sampled with nets in Regions 0, I, II, and III were 54, 95, 58 and 77%, respectively. Region 0 was sampled only during the last 11 months of the investigation, and hence overall effort was relatively low (Fig. 2). A relatively high level of effort was expended between RM 29.0 and 31.9 (above South Canyon) following the discovery of a disjunct aggregation of humpback chub associated with the Fence Fault springs. Netting in Region I occurred primarily between RM 57.0 and 65.9 (Kwagunt Canyon and Lava Canyon), with peak effort between RM 61.0 and 61.9 (LCR confluence), to sample the mainstem component of the LCR population. Peak netting effort in Regions II and III was between RM 108.0 and 108.9 (Shinumo Creek inflow), and RM 213.0 and 213.9 (near Pumpkin Spring), respectively. Most netting in Region II occurred near mouths of tributaries (i.e., Bright Angel Creek, Shinumo Creek, Tapeats Creek, and Kanab Creek), and the relatively low percentage of 1-mile sections sampled (58%), combined with the highest percentage of netting effort (41%) attest to the steep gradient, narrow channel, and swift currents that limited net-set locations in this region.

Electrofishing. The percentages of 1-mile sections sampled by electrofishing in Regions 0, I, II, and III were 67, 95, 75 and 89%, respectively. Relative level of effort for electrofishing was similar to that of netting in all regions (Fig. 2). Effort within Region 0 was low, with a peak occurring between RM 30.0 and 30.9 (above South Canyon). Peak electrofishing effort in Region I occurred between RM 64.0 and 64.9 (Carbon Creek area), with intensive sampling between RM 57.0 and 64.9 (Kwagunt Canyon to Lava Canyon). As with netting, peak electrofishing effort in Region II was around Shinumo Creek, RM 108.0-108.9. In Region III, effort peaked between RM 214.0 and 214.9 (near Pumpkin Spring).

Temporal Sampling

Seasonal sampling was conducted by spring (March-May), summer (June-August), fall (September-November), and winter (December-February). Distribution of sampling by season was determined primarily by the number, duration, and purpose of field trips for each 3-month period. Trips in October, November, and December of 1990, and no December trips in 1991, 1992, or 1993 disproportioned fall and winter sampling efforts. Sampling with the four primary gear types was approximately proportionately distributed by season, except for seines (Table 1). Disproportionately less area was seined in summer than in other seasons of the year, and more area was seined in spring and fall, the result of directed sampling to assess humpback chub cohort strength before and after departure of young chub from the LCR to the mainstem. Nevertheless, magnitude of sampling with the various gear types provided an adequate seasonal characterization of species composition, distribution, and abundance.

Diel sampling was conducted by day, night, dawn, and dusk. Because day length varied by season, diel sampling blocks were adjusted according to ambient light conditions (Sun and Moon Events Worksheet, Heizer Software, Inc. Palo Alto, CA). Sunrise and sunset for a given trip were calculated on the basis of longitude, latitude, and elevation for a date midway through the corresponding field trip. Night was defined as the period from 2 hrs after sunset to 2 hrs before sunrise, dawn was 2 hrs before sunrise to sunrise, day was from sunrise to sunset, and dusk was sunset to 2 hrs after sunset.

Diel sampling with nets and electrofishing was disproportionately greater at dawn and dusk (Table 2), primarily because project objectives from October 1990 through November 1992 required handling large numbers of humpback chub for radiotelemetry, habitat evaluation, and mark-recapture population estimates. Humpback chub were most active during mornings and evenings when they were, most susceptible to capture. Sampling was also conducted during night and day to insure adequate diel coverage, but effort had to be balanced with logistical constraints (e.g., weight of gasoline to run research boats day and night) and fatigue experienced by crew members from sampling during the four time blocks.

Diel distribution of netting and electrofishing effort by region better illustrates the effect of project objectives on sampling intensity (Table 3, Fig. 4, Fig. 5). Sampling in Region I was directed at maximizing catch of humpback chub; netting effort occurred primarily between 1600 and 2000 hrs, and electrofishing effort occurred primarily between 1800 and 2200 hrs. Effort in Regions II and III was more evenly distributed between dawn (0600-1000 hrs) and dusk (1600-2200 hrs), still reflecting an effort to capture humpback chub during periods of greatest susceptibility (essential for locating disjunct aggregates or individuals) with logistical and personnel constraints.

Distribution of netting effort for ambient light conditions was similar among the four study regions (Fig. 6). Most netting effort occurred during the day, followed by dawn/dusk and then night. Distribution of electrofishing effort between ambient light conditions was similar to netting effort, except for slightly higher effort at night than at dawn/dusk in Region I. All seining and angling were conducted during the day. Hoop nets and minnow traps were typically set during the day and checked every 12 or 24 hrs.

Sampling Gear Efficiency

A variety of active and passive gears were used to provide a characterization of species abundance and distribution in a range of habitat types. Similar gears and techniques were used to facilitate data comparison with other native fish sampling programs in Grand Canyon, as well as other regions of the Colorado River Basin. Selected gear types were used because of their effectiveness on particular species or sizes of fish in given habitats, and to provide reliable data for comparative catch rate statistics. Each gear type was used according to specified protocol to maximize efficiency and reduce variability.

Sampling gear efficiency and statistical variability were primary considerations in sampling design, gear type selection, and sampling techniques, because of potential effect on catch statistics and general characterization of fish populations. Although sampling was stratified to reduce variability, season, water temperature, water level, turbidity, fish behavior, and experience of personnel can affect efficiency, and possibly catch statistics (Hubert 1983, Hayes 1983). Other variables were specific to gear types and techniques. For example, duration of netting effort influenced sampling results, since fish do not continue to accumulate in nets at a uniform rate; efficiency of gill nets decreases with numbers of fish (Austin 1977). Gill and trammel nets were set for a maximum of 2 hr to account for this 'saturation' effect.

Twenty-three gear types were used to sample the four study regions from October 1990 through November 1993 (Table 4). Fifteen were passive gears, including 11 types of entanglement nets, three types of hoop nets, and minnow traps. Eight active gears were used, including electrofishing, five sizes of seines, and two methods of angling. Adult humpback chub were captured with 18 of the 24 gear types, juveniles with 12, and YOY with seven.

Collectively, sampling gears effectively captured all age categories of humpback chubs (i.e., YOY, juvenile, adult), and fish that ranged in size from 23 to 480 mm TL (Fig. 7). Gill and trammel nets were most effective at capturing adult chub, while most subadults (YOY and juveniles) were caught with seines, electrofishing, and minnow traps. Experimental gill nets were effective on all age categories (Fig. 8). Hoop nets and angling were not included in the analysis because these gears captured few humpback chub.

Pooled length-frequency analysis of humpback chub captured by these gear types (experimental gill nets; gill and trammel nets; electrofishing, minnow traps, seines) revealed a bimodal distribution, with peaks at 60 mm and 380 mm TL (Fig. 9). The relatively lower numbers of fish between 150 mm and 300 mm TL indicates decreased gear efficiency for this size range. Comparison of gear potential (e.g., mesh size) with fish size (e.g., fish body depth) did not reveal decreased efficiency for the intermediate size fish. Alternately, the size class structure represents a long-lived species with low survival of young and low recruitment.

Catch rates for each gear type by region are presented for humpback chub (Table 5), flannelmouth suckers (Table 6), bluehead sucker (Table 7), and rainbow trout (Table 8).

Nets

Eleven types of gill and trammel nets were set 10,800 times (22,532 hrs) in the course of the study (Table 4). Generally, all net types were used extensively in all study regions (Table 5). Length and mesh size of nets, as well as specifications of other gear types, are presented in English units for clarity and consistency with other reports.

Trammel nets were about twice as effective as gill nets at capturing adult humpback chub (Fig. 10). Trammel nets often entangled the fish more effectively than gill nets. Trammel nets are also much less size selective than gill nets, and therefore capture more fish (Hubert 1983). In 1993, floating trammel nets (TY and TZ) were used to investigate near surface activity of humpback chub, but these nets fouled easily, and few efforts were made.

Humpback chub were captured with all net types except TW (0.5 inch mesh trammel net) and GZ (60 ft experimental net) (Table 4). Adult chub were captured with nine net types, juveniles with five, and YOY were captured only in experimental gill nets (GX).

Humpback chub GM_{CPE} (geometric mean catch per effort) was highest for trammel nets (Table 4). There was no significant difference in humpback chub GM_{CPE} between 1.5 and 2 inch mesh gill nets, or between 1 inch and 1.5 inch mesh trammel nets (Student's T-Test; $P \leq 0.05$). There was a positive relationship between net mesh size and humpback chub total length; 2 inch gill nets (GM) collected significantly larger chub than 1.5 inch gill nets (GP), and 1.5 inch trammel nets (TL) caught significantly larger chub than 1 inch trammel nets (TK) (Student's T-Test; $P \leq 0.05$).

Size distribution of humpback chub was compared between individual net types or pairs of net types which differed only in the length of the net. Both juvenile and adult humpback chub were captured with standard gill and trammel nets (i.e., GX, GM, GP, TL/TN, TK/TM). The combined range of sizes of chub captured with these gears was 130 to 490 mm TL (Fig. 11, 12). Equal numbers of juveniles and adults, were captured with experimental gill nets (GX,) but this net type fouled easily with Cladophora, and seemed relatively stressful on small fish since their more fusiform shape allowed the mesh to slip tightly over the body and gill opercles. Size distribution within net types was bell-shaped except for GX and TK/TM.

The size distribution of humpback chub captured with experimental gill nets (GX) had three modes, corresponding to different mesh size. There were two distinct modes in the size distribution of chubs captured with TK and TM nets (1 inch mesh). One mode occurred at 220 mm TL and the other at 370 mm TL. This bimodal distribution may reflect the shape of the humpback chub. Typically, a fish must wedge itself between the strands of mesh to become entangled in a net; field observations indicate this wedge formed either about the head or back of entangled humpback chub. TK/TM (1 inch mesh) nets may have entangled relatively large chubs by the head and smaller chubs by the back, but few sizes in between because the head girth of intermediate-sized fish was too small to form a wedge and the back girth too large to fit between the mesh.

Hoop Nets

Large, medium and small hoop nets (HL, HM, HS, respectively) were set a total of 63, 17 and 86 times, respectively (Table 4). Six humpback chub were collected from these sets, including four adults, one juvenile and one YOY. Of these, three were collected in Region I and three in Region II (Table 5). Hoop nets were used primarily in Regions II and III; their use in Regions 0 and I was restricted by relatively high maintenance (i.e., cleaning the traps of Cladophora), lack of suitable habitat for this gear (i.e., tributary inflows), and better efficiency of other gears. Small sample size precluded comparison of catch rates between the three sizes of hoop nets.

Minnow Traps

Unbaited minnow traps (MT) were set 4,562 times (85,111 hrs) (Table 5). A total of 928 subadult humpback chub were captured at a rate of 1.1 fish/100 hr. Minnow trapping effort was concentrated in Region I where the highest concentration of subadults occurred (Table 5); 98% of the total minnow trap catch of subadults occurred in Region I. Minnow traps were valuable at capturing subadult humpback chub in low velocity habitat with relatively little effort.

Escapement of juvenile humpback chub from minnow traps was documented in 1992. While conducting habitat measurements in the late afternoon along a shoreline set with minnow traps, a biologist noticed two juveniles in a minnow trap which had been set several hours earlier that day. The fish were gone when the trap was checked the following morning. Hence, beginning in 1993, traps were checked twice daily (approximately every 12 hrs) to lessen the potential for escape.

Large numbers of YOY and juvenile humpback chub were captured with minnow traps. Length range of chubs captured in minnow traps was 30-180 mm TL, with a mode between 50-60 mm TL (Fig. 13).

Catch rates of subadult humpback chub (GM_{CPE}) were significantly higher under high turbidity (t-test; $P \leq 0.05$). This analysis included only humpback chub captured in Region I below RM 61.9 (below LCR), where the majority of subadult humpback chub occurred. The effect of turbidity on catch rates in minnow traps is not well understood. Possibly young chubs frequent shallow shorelines under the cover of turbidity, and hence greater numbers of fish are available to shoreline minnow traps. The young fish may also avoid the traps when visible, but stray into them when water clarity is low. Also, escapement may be higher under high visibility.

Electrofishing

A total of 2,886 electrofishing runs (784 hrs) were conducted (Table 4). Electrofishing accounted for the largest number of humpback chub captured by any gear type (2,177 total, 1,272 YOY, 767 juveniles, 138 adults). Electrofishing was used extensively in all study regions (Table 5).

Electrofishing was the only gear type that captured relatively large numbers of all age categories of humpback chub. The size range was 20 - 460 mm TL although the distribution was skewed toward smaller individuals, with a mode at 40 - 50 mm TL (Fig 13).

The electrofishing system used in Grand Canyon was relatively inefficient compared to other systems used to sample native fish in the upper Colorado River basin, as described by Snyder (1992). We noted, as have numerous other biologists (Snyder 1992), that the Coffelt Mark XX CPS system used in Grand Canyon was noticeably less effective at inducing taxis than the widely used Coffelt VVP-15, and hence fewer fish were caught with the Mark XX.

Also, the electrode configuration used in Grand Canyon was a spherical anode and cathode (made of stainless steel) of equal size suspended near the water surface. This system effectively captured small humpback chub in shallow shoreline habitat, but was relatively ineffective in deeper water. A cable cathode of the same surface area as the anode can be lowered into deep water to effectively draw fish from greater depths.

Effectiveness of electrofishing and injury to fish are largely dependent on the electrode configuration of the system; current and voltage distribute about the electrode in a complex way and this distribution is critical to electrofishing effectiveness (Reynolds 1983). Overall effectiveness is directly related to current density, and current density is directly related to fish mortality (Reynolds 1983); hence the design of the electrofishing system must be balanced between the accepted mortality risk and the desired effectiveness.

Significantly fewer fish were caught with electrofishing in the day and in low turbidity than at high turbidity or at night (t test, $P \leq 0.05$). Possibly the fish used shallow shoreline areas more frequently at night or in high turbidity, where they were more available to shoreline electrofishing.

Seines

A total of 524 standard seine hauls (three types of seines: SA, SB, SG) and eight sweeps with floated nets (GF and TF) were taken in 1990-93 (Table 4). Standard seine hauls yielded 1,385 humpback chubs (930 YOY, 444 juveniles and 11 adults). Seining occurred in each study region but effort was concentrated in Region I, where subadults were concentrated (Table 5). Ninety-eight percent of all humpback chub captured with seines were in Region I.

All age categories of humpback chub were captured with seines (Fig. 14). These fish ranged from 20 to 180 mm TL for SA and 20 to 410 mm TL for SB/SG. Significantly larger humpback chub were captured with 1/8-inch mesh seines (SA) than with 1/4-inch mesh seines (SB/SG) (t-test; $P \leq 0.05$), although minimum size captured with each was identical.

In 1993, efficiency of seine hauls was directly related to water turbidity; GM_{CPE} was significantly higher (t-test; $P \leq 0.05$) in high turbidity than in low turbidity below RM 61.9. Insufficient data precluded analysis of catch rates in 1992. These data suggest that subadult humpback chub avoided shallow shoreline habitat under clear water conditions during the day. Kaeding and Zimmerman (1983) reported similar findings and speculated that subadult humpback chub used shallow littoral areas only during darkness and periods of high turbidity. Increased escapement of fish because of high researcher visibility in the daytime was discounted based on field observations.

Angling

Less than 2 hrs was spent angling with bait in Region I during 1990-93 (Table 4). Effort was limited because of concern over the risk of a humpback chub swallowing a hook. Two adult chub were captured and were in good condition. Total effort for angling with lures was not available because of inconsistencies in recording sampling effort in the field. Overall, angling effort was limited by time constraints and higher efficiency of other gears. Typically, 1-10 hr of angling were logged each trip in 1993. One adult chub was captured angling with lures in Region I (Table 5).

Catch by Gear Types

Nets

Twelve species of fish were captured with gill and trammel nets in the Colorado River in Grand Canyon during 1990-93, including four native species and eight non-natives (Table 9). Of 7,167 fish captured in nets the majority were rainbow trout (38%), followed by humpback chub (24%) and flannelmouth sucker (23%).

Nets captured primarily adult humpback chub, rather than subadults, as well as adults of other large species. Rainbow trout were the dominant adult fish species captured with nets in Regions 0 and I, comprising 93% and 39% of total catch, respectively. Humpback chub comprised 3% and 34% of captures in Region 0 and I, respectively. Flannelmouth suckers (35%) and common carp (33%) were the dominant adult species captured with nets in Regions II and III, respectively, and humpback chub comprised 11% and 2% of the total net catch of adults in Regions II and III, respectively.

Hoop Nets
Ten species of fish were captured in hoop nets including four native species and six non-natives (Table 9). Of 936 fish captured in hoop nets the majority were bluehead suckers (39%), followed by flannelmouth suckers (30%) and rainbow trout (22%).

Minnow Traps
Nine species of fish were captured in minnow traps including four native species and five non-natives (Table 9). Of 1,349 fish captured in minnow traps the majority were humpback chub (69%), followed by speckled dace (21%) and fathead minnows (6%).

Seines
Ten species of fish were captured with seines, including four native species and six non-natives (Table 9). Of 3,682 fish captured with seines the majority were humpback chub (40%), followed by fathead minnows (19%) and speckled dace (12%).

Nearly all fish captured with seines were subadults. Overall, humpback chub were the dominant subadult species captured with seines, comprising 64% of the total catch. Total catch of subadult fish in Region 0 was comprised of six rainbow trout. Humpback chub were the dominant species in Region I, comprising 79% of all subadults captured, while flannelmouth suckers were dominant in Region II and III, comprising 26% and 34% of total catch, respectively. Humpback chub comprised 22% and 1% of the total subadult catch in Regions II and III, respectively.

Electrofishing
Fourteen species of fish were captured electrofishing, including four native species and ten non-natives (Table 9). Of 14,971 fish species captured electrofishing the majority were rainbow trout (53%), followed by humpback chub (15%) and common carp (13%).

Both adult and subadult humpback chub, as well as other species, were captured electrofishing. Overall, rainbow trout were the dominant adult fish captured electrofishing, comprising 60% of the total catch. Rainbow trout were the dominant species of adults in Regions 0, I and II, comprising 94%, 77% and 44% of the total electrofishing catch, respectively. Common carp were dominant adults in Region III, comprising 68% of the total catch. Humpback chub comprised >1%, of the adult fish captured electrofishing in Regions 0, II and III, and comprised 3% of the total catch in Region I.

Overall, subadults captured electrofishing were dominated by humpback chub, comprising 56% of the total catch. Rainbow trout, however, dominated Regions 0, II and III, comprising 99%, 66% and 43% of the total subadult catch in the respective regions. Subadult humpback chub comprised 78% and 2% of the total electrofishing catch in Regions I and II, respectively. No subadult humpback chub were captured electrofishing in Regions 0 or III.

Angling
Two fish species, humpback chub and rainbow trout, were captured angling. Three humpback chub were captured; total count of rainbow trout captured was not recorded.

Evaluation of Marking Techniques
Humpback chub, flannelmouth sucker, and bluehead sucker were marked with PIT tags (Burdick and Hamman 1993, Prentice et al. 1990a). Retention of PIT tags was evaluated by examining scars on

recaptured fish. Changes in total length and weight were calculated for fish at large greater than 30 days to evaluate effects of PIT tags on physiological condition.

BIO/WEST and other investigators PIT-tagged approximately 8,500 humpback chub in Grand Canyon from October 1990 through November 1993 (Fig. 15). Of these, B/W captured and tagged 983 in the mainstem Colorado River (Table 10). Approximately 28% of the fished marked by B/W were recaptured by B/W (Table 11). Of 78 radio-tagged fish, 23 (29%) were recaptured. Scars were noted on four humpback chub where no PIT tag was detected; the scars were immediately posterior to the base of the pelvic fins which was the standard injection site for the tags. The absence of a PIT tag is attributed to (1) improper tag injection, (2) tag failure (i.e., tag was broken or malfunctioned), or (3) receiver malfunction. Hence, overall loss rate for PIT tags was estimated at less than 1% (4 of 8,500).

In addition to PIT tags and radio tags, 1,063 juveniles or YOY chub were marked by B/W with dorsal or caudal fin punches. Only 12 of these marked fish were recaptured. Of these, most fins were regenerated, but the deformity of fin rays was evident and may be a permanent mark identifying previously marked fish.

Flannelmouth suckers and bluehead suckers in Grand Canyon were first PIT-tagged in fall of 1991. Hence, totals of 1,071 and 394 fish, respectively, were tagged through November 1993 (Table 12); 176 (16%) and 13 (3%) were recaptured, respectively.

Numerous native fish were captured with either Carlin or Floy (FD-67) tags attached by previous investigators including 50 Carlin tags and 27 Floy tags from humpback chub and 1 Carlin tag and 23 Floy tags from flannelmouth suckers and bluehead suckers (Table 13).

Relative condition factor (Kn) was compared between recaptured humpback chub (separate for PIT, Carlin, and Floy tags) and adults captured for the first time. There was no significant difference (t test, $P \geq 0.005$) in Kn between these recaptured fish and initial captures (Table 14). Also, no significant length changes or weight losses were noted for humpback chub that were recaptured up to nine times (Table 15), indicating no detrimental effect of PIT tags.

Differences in length and weight measurements were estimated from 60 humpback chub (range, 20-480 mm TL) recaptured within 36 hr of initial capture to evaluate accuracy of field measurements. The mean difference in total length was 0.43 mm, (range, -13 to 23 mm), and the mean difference in weight was 4.5 g, (range, -82 to 84 g). Several factors may have contributed to weighing error. There may be inherent error in the weighing scale or scales used by different researchers. Most humpback chub were processed on a beached boat which could be affected by wind and wave action, making the scale difficult to "tare". Moisture accumulated in holding boxes may have affected scale sensitivity. Also, the amount of water allowed to drip from a fish prior to weighing probably varied. An effort was made to standardize the weighing procedure as follows: (1) the boat was tied to shore and stabilized, (2) the scale was tared each time before measuring a fish, (3) the fish was carefully lifted from the live well and excess water allowed to drip for several seconds, and (4) the fish was gently placed in the center of the scale dish, until the fish was still, and the display had stabilized to insure accuracy.

Fish weight was also affected by the physiologic condition of the fish. Fish captured prior to spawning were more robust than those captured immediately after spawning, and a fish with food in its gut weighed more than one prior to feeding.

EVALUATION OF FISH INJURY

This section presents an evaluation of fish injury that resulted from sampling methods used during this investigation. Where possible, mortality and injury rate are presented for a specific technique. Modifications of techniques made during the course of this investigation are discussed and recommendations are made regarding future use of techniques in Grand Canyon.

Fish Handling Methods

The Data Collection Plan (Supplement No. I) developed by B/W contains a description of fish handling procedures that details the methods used for handling fish. Every effort was made to minimize stress to fish during this investigation.

Holding Facilities

All fish captured were immediately transferred to live wells for processing. Each sampling boat was equipped with 80 or 120 qt coolers that served as live wells. Insulated coolers maintained relatively constant water temperatures, especially during summer months when ambient air temperature was routinely greater than 30°C. Five gallon buckets were also used as live wells to hold YOY and juveniles during seining and minnow trapping. Care was taken to keep buckets shaded and water was exchanged frequently when large numbers of fish were held in these containers prior to processing and release.

No mortalities directly associated with holding fish were documented during this investigation. However, stress associated with holding fish was observed, especially if fish were held in crowded conditions for periods longer than 15 to 20 min. Sampling protocols during the early phases of this investigation required holding humpback chub for periods of up to 1 hr while they were transported to a central processing station to be photographed and video taped under controlled conditions. Meristic measurements during the first year of the study also increased holding time. During this time, much effort was made exchanging water in coolers and monitoring the condition of fish. Fish that showed signs of excessive stress were immediately returned to the river with only minimal processing (i.e. length, weight and PIT tag). Signs of stress included lethargy, sliming, reddening of the fins and skin, and loss of equilibrium. As the study progressed, sampling protocols were modified to minimize holding time for fish. Modifications included processing fish on the boats, rather than transporting them to a central station, eliminating video taping, and subsampling fish for meristic measurements. It was felt that reduction in holding time markedly decreased stress to fish.

The only mortality of humpback chub related to holding fish, occurred when YOY and juveniles leaped from the live well during electrofishing runs. This accounted for the loss of three humpback chub. The problem was corrected by placing subadult humpback chub in a separate covered compartment of the live well.

Methods for Weighing, Measuring, and Photographs

Weighing, measuring, and photography of fish were done consistent with handling and data collection protocols established at the beginning of the study. Direct mortality associated with these handling procedures was not observed, although stress observed if the fish were dropped or held out of the water for excessive time.

Fish Capture Methods

Of 6,294 humpback chub captured and processed by B/W from October 1990 through November 1993, a total of 19 humpback chub died incidental to capture, handling, or processing (Table 16). Of these, 13 were related to fish capture methods, two were found dead of unknown causes, one died following stomach pumping, and one death was related to radiotagging. One injured humpback chub was sacrificed to investigate a possible infestation of Asian tapeworm, and one was euthanized for examination of possible spinal injury associated with electrofishing. Specific effects of each sample gear type on fish captured are presented below.

Gill and Trammel Nets

Netting was a safe, effective means of sampling humpback chub in the Colorado River in Grand Canyon. Direct, net-caused mortality was reported for two humpback chub during the course of this study (Table 17). One chub died during removal from a net by non-staff personnel, and one was entangled in debris during a flood and was not seen by biologists removing fish from the net. A third humpback chub was found laying against a trammel net; the fish was rigored and probably died of other causes not associated with the net.

Overall, humpback chub captured in nets sustained few apparent gear-related injuries. Humpback chub, in contrast to trout, struggled very little following entanglement and were quickly and easily removed from nets. Of 1,721 humpback chub captured with nets, seven were visibly stressed, two had external injuries inflicted by the nets (e.g., bruises, torn opercle), and seven had injuries possibly inflicted by the nets (e.g., abrasions, lesions). Some humpback chub captured in nets had torn or split fins; these were not included in the analysis of injuries because these were not considered serious enough to effect fish health. All visibly stressed humpback chub were successfully revived and released immediately after capture without completion of processing. Typically, stressed chub had swallowed air when removed from the water and had difficulty maintaining equilibrium in the live well. Most fish seemed able to self-regulate within minutes, but in extreme cases, gentle massaging of the fish's belly helped expel the air.

Mortality of other native species captured in nets was also minimal. Of 1,696 flannelmouth suckers captured in nets, only three died. Of 293 bluehead suckers captured in nets, two died. No specific information is available on gear-related non-lethal injuries to other native species, but field observation revealed few injuries.

Rainbow trout, the dominant non-native species captured in nets, were more susceptible to injury inflicted by nets. A total of 148 of 2,754 (5%) rainbow trout captured in nets were known dead. Latent mortality of net-captured rainbow trout is likely very high -- many rainbow trout captured alive in nets were extremely stressed and likely did not survive.

Hoop Nets

No humpback chub died in hoop nets or exhibited any apparent gear-caused injuries (Table 17). Of 283 flannelmouth suckers and 363 bluehead suckers captured in hoop nets, one of each species died; the specific cause of death was not known. One of 203 rainbow trout captured in hoop nets was discovered dead.

Minnow Traps

Seven of 928 humpback chub were found dead in minnow traps (Table 17). The cause of death of these fish was undetermined. It is possible that changes in flow pulled the traps into deeper, more turbulent water, and either entrained the fish to the sides of the trap or otherwise created stressful conditions. Dewatering of areas with traps was not considered a factor since traps were set in sufficiently deep water and desiccation of areas during fluctuating river flows was not observed. One flannelmouth sucker died in a minnow trap; no mortalities of bluehead suckers or rainbow trout was observed.

Seines

One subadult humpback chub died in a seine (Table 17). The fish apparently suffocated in mud while fish were being sorted from the seine haul. One flannelmouth sucker and one rainbow trout died from seining in 1990-93.

Electrofishing

Four humpback chub died from electrofishing (Table 17). Three of these fish were juveniles that leaped from the live well during electrofishing and were found in the boat afterward (see **Holding Facilities**). In November 1991, one juvenile and one adult humpback chub, captured in the same electrofishing run, showed signs of stress including loss of equilibrium and lethargy. The juvenile was held and observed for about 10 hr and released following apparent recovery. The adult was held for 30 min and released, but recaptured 3 days later by electrofishing 6.7 km downstream. The fish appeared sluggish, never regained equilibrium, and died after 19 hr. An X-ray of the carcass did not reveal evidence of spinal injury.

In 1990-91, external injuries attributed to electrofishing were observed on three fish species: humpback chub, rainbow trout, and brown trout. These injuries were classified as "bruise marks" (blackened, saddle-shaped area extending across the back at the posterior end of the dorsal fin), "spinal deformity" (evident spinal misalignment or swimming difficulty), "equilibrium loss" (inability of fish to remain upright), "extended narcosis" (apparent loss of consciousness for more than 5 min), or "unspecified" (undetermined or undescribed, but apparent effect).

Ninety-three of 11,543 fish (0.8%) captured electrofishing exhibited external injuries (Table 18). This included 81 rainbow trout (75 adult, 6 juvenile), six adult brown trout, and six humpback chub (4 adult, 2 juvenile). The most common effect (0.6%, n=64) was "bruise marks". Adult rainbow trout had the highest incidence of "bruise marks" and "spinal deformities". Humpback chub showed no evidence of bruise marks from electrofishing, although three exhibited extended narcosis but eventually recovered and were released. In September 1991, one juvenile chub was observed with spinal deformity posterior to the dorsal fin. The fish was released after 8 hr when it regained equilibrium and was swimming normally. Also, two fish exhibited loss of equilibrium but recovered. Typically, YOY and small juvenile humpback chub (approx. range, 50-150 mm TL) did not show signs of stress following electrofishing.

Overall, electrofishing was considered an effective sampling technique for capturing subadult humpback chub in Grand Canyon with a low incidence of injury (Cowdell and Valdez 1994). Electrofishing was most effective with less evidence of injury at output levels of 200-250 V, and 8-10 A. Small fish are less affected by electrofishing because, at a given voltage gradient, total body voltage increases with length resulting in greater electroshock to larger fish (Reynolds 1983). Thirtynine of 7,977 rainbow trout died from electrofishing (Table 19). As with netting, latent mortality of rainbow trout may have also occurred from electrofishing.

Angling

No fish died as a result of angling during this study. Most angling effort was with lures which greatly reduced the potential for injury from fish swallowing a hook.

Fish Marking Methods

PIT Tags

A total of 1,075 humpback chub were PIT-tagged by B/W during this investigation. No direct mortalities associated with PIT tagging procedures were documented. Potential adverse effects associated with this technique included bleeding, perforation of internal organs, and handling stress. Actual number of fish that bled as a result of PIT-tagging was not documented, but estimated to be 3-8%. The numbers of fish with perforated internal organs could not be document, but was believed to be small. This effect was minimized by holding the fish upside down and injecting the tag into the parietal space created between the intestine and pelvic girdle. Extra handling time associated with PIT tagging procedures did result in increased stress to fish, but was considered negligible compared to stress from capturing and holding. Observations of 1,154 PIT-tagged fish recaptured by B/W indicated no obvious long term effects (e.g. infection or extremely poor condition) associated with the technique that could have resulted in mortality.

Effects of PIT-tagging on overall fitness of humpback chub were evaluated by using relative condition factor (Kn) of adults recaptured from one to nine times (Table 19). Since recaptured fish included those shared in common between the mainstem and LCR, Kn was calculated for all adult humpback captured in either the LCR or mainstem. Although the data suggested a trend of declining fish condition with numbers of times handled, differences in Kn between adjact values were not significant. Effects associated with the PIT-tag implant procedure would have been most apparent between initial capture (n=5,679 fish) and those recaptured one time (n=756 fish). Condition factor (Kn) was higher for the group of fish recaptured once, indicating that deleterious effects of PIT-tagging were minimal, although individual fish may have suffered adverse long term effects that were not detected by this analysis. PIT-tagging provided a reliable long-term marking technique for humpback chub that appeared to have little adverse effect on the fish. The procedure is recommended for future studies of native fish in Grand Canyon with the continued precaution that individuals injecting PIT tags should be thoroughly trained.

PIT tags have been used extensively in marking many species of fish, particularly large numbers of young salmon. PIT-tag retention was nearly 100 percent for juvenile salmonids, and the tags did not adversely affect growth or survival (Prentice et al. 1990b)

Fin Punches

A total of 1,249 YOY and juvenile humpback chub (range, 60-150 mm TL) were fin-punched during this investigation including 1,063 by B/W and 186 by AGF. No direct mortalities associated with this technique were noted. Other adverse effects associated with excessive fin damage and additional handling were observed, but were not quantified.

Twelve fin-punched fish were recaptured during the study. Of these, fin regeneration was documented for two fish. The remaining fish were probably recaptured shortly after release before fins had time to heal. Since fin punch combinations were coded for location rather than time, it was not possible to evaluate retention of the mark. It was speculated that fin punches may have provided identifiable marks for 1 to 3 months. Hence, fin punching of humpback chub in larger-scale studies is not recommended. However, for small-scale, short-term studies (e.g. evaluating movement of young humpback chub in and out of backwater habitats) the technique may provide a suitable method for marking small numbers of fish for short time periods.

Radiotelemetry

Radiotelemetry was the most intrusive technique used in this investigation. Direct effects to fish associated with this technique included prolonged holding periods, use of an anesthetic, and abdominal surgery. No direct or short-term mortalities, occurred as the result of radio implant. Indirect or long-term effects were more difficult to quantify. Use of an external antenna increased chances of long-term effects since this made complete closure of the body cavity difficult. Possible long-term effects include reduced fitness, decreased fecundity, tissue necrosis, or other secondary infection.

One radio-tagged humpback chub died during this investigation. This latent mortality was suspected to be caused by infection resulting from surgical procedures. The fish was recaptured in poor condition 87 days following implant. The poor condition was attributed to a severe infection believed to be caused by bacterial invasion of the parietal cavity through either the abdominal incision or the antenna exit. Three other radio-tagged fish were tracked for a short period (7 days or less) and remained unaccounted for the duration of the study. Premature loss of contact was attributed to transmitter malfunction, movement by the fish from the tracking area, or the fish died and sank into deep water out of signal-reception range. Most likely, contact with these fish was lost because they moved from the tracking area, either into the LCR or to a downstream reach that was not routinely monitored by field crews. For example, one radio-tagged fish was tracked for only 1 day before contact was lost, and the fish was subsequently recaptured in good condition in the LCR, 547 days later. One of these fish was inadvertently captured electrofishing one day following implant, and the additional stress resulted in its death. Hence, known mortality of radio-tagged humpback chub was 1 of 75, or 1.3%.

Other effects including decreased fitness or reduced fecundity were evaluated based on condition of recaptured fish and are discussed in more detail below.

Surgical Procedures

During the course of the study, surgical procedures were modified to reduce surgery time, minimize risk of post- surgical complications (i.e., infection, incision dehiscence), and expedite healing and recovery by the fish. Surgical techniques were modified three times from the original procedure (Table 20). Modifications involved changing suture material from non-absorbable Gortex® to absorbable Maxon® sutures, changing techniques for exertion of the external antenna, and relocating the site of the primary incision. Effects of each procedure were evaluated as: (1) effects directly related to surgery (i.e., time needed to complete the procedure, difficulty of the procedure, and affects to the fish such as bleeding or slow post-surgical recovery), and (2) long-term effects such as healing rates, infection, or mortality. Evaluation of factors directly related to surgery was based on observations and judgement of biologist performing the surgery. Long-term effects were evaluated based on condition of recaptured radio-tagged fish and observations made while radiotracking.

Midline Incision, Gortex Sutures, Mosquito Forceps (MGM). In the original procedure (i.e., MGM), the primary incision was located along the midline on the belly of the fish (i.e., linea alba) between the pectoral and pelvic girdles. The antenna was exerted through the body cavity by using mosquito forceps to guide the antenna to the exit site, and a small incision was made over the forceps for an exit opening. The primary and antenna incisions were closed with Gortex® non-absorbable sutures.

Midline Incision, Maxon Sutures, Mosquito Forceps (MMM). Procedure MMM was similar to the original procedure, except that Maxon® absorbable sutures were used instead of Gortex® sutures. This modification was made when observations of recaptured radio-tagged fish indicated that sutures were not being incorporated into tissues as anticipated; some suture sites appeared irritated and infected. Possibly the Gortex® sutures were wicking external moisture and providing a conduit for bacteria or other sources of infection. All subsequent procedures utilized Maxon® absorbable sutures.

Midline Incision, Maxon Sutures, SNAG (MMS). The third procedure, MMS, utilized a modified technique for exerting the antenna through the body cavity. Instead of using mosquito forceps as described above, a stainless steel, sheathed needle (sheathed needle antenna guide - SNAG) was used to guide and exert the antenna through the body cavity. This modification was made to provide better closure of the antenna exit and to reduce the possibility of infection. Mechanical injury associated with the flexible antenna moving in the water continually damaged the tissue around the antenna exit resulting in delayed healing of the incision and infection. The SNAG eliminated the need for an incision and sutures at the antenna exit and reduced mechanical damage to tissues caused by movement of the antenna.

Lateral Incision, Maxon Sutures, SNAG (LMS). The fourth procedure, LMS, involved relocating the midline site of the primary incision laterally by 1-1.5 cm. This modification was done to evaluate differences in healing time between the two incision sites. Midline incisions were used initially based on techniques established by Hart and Summerfelt (1975), Marty and Summerfelt (1986), Bidgood (1980). Midline incisions were believed to minimize nerve and muscle damage as well as reduce bleeding during surgery because of the lack of vascularization in the linea alba. Techniques involving lateral incisions were established by Tyus (1988) for Colorado squawfish and razorback suckers and were used extensively in the Upper Colorado River Basin for implanting radio tags in endangered fishes (Valdez and Clemmer 1982, Kaeding et al. 1990, Valdez and Masslich 1989). Tyus (1988) felt that lateral incisions reduced irritation of sutures by visceral wall pressure, and lessened the likelihood of abrasion of sutures on the river bottom. We believe that vascularization in the lateral wall, although resulting in some bleeding during surgery, reduced healing time of the incision.

Short-Term Effects

The degree of lethargy or loss of equilibrium in recently implanted humpback was no greater than in other fish handled. Fish were never completely anesthetized during surgery and recovery was initiated during closure of the incision. Hence, fish returned to the recovery live well were swimming normally within about 15 sec and were released soon after surgery.

Differences in the surgical procedures that affected time needed for surgery, ease of technique or effects to the fish were minimal. Procedures that utilized the SNAG (i.e., MMS and LMS) were faster by 30-60 sec than other techniques because suturing was not necessary around the antenna exit. Differences in site of the primary incision (midline versus lateral) were also negligible. Bleeding was more common with lateral incisions, but was also observed in midline incisions and was highly variable between fish.

Long-Term Effects

Twenty-eight radio-tagged fish were recaptured a total of 34 times (Table 21). Two fish were recaptured twice and one fish was recaptured four times. Number of days these fish were at large ranged from 33 to 969 days. Each time a radio-tagged fish was recaptured, standard data were collected (i.e. total length and weight), the primary incision and antenna exit were examined, and various aspects of the fish including the incision and antenna exits were photographed,. Condition of primary incision and antenna exit were evaluated in the field and classified as good (i.e., slight or no inflammation, healing, or healed), fair (i.e., moderate inflammation and/or mild infection), or poor (i.e., dehiscent incision or open antenna exit, infection present). Fish recaptured by other investigators were evaluated on the basis of notes and photographs from field personnel.

Of the 34 recaptures, the condition of the incision and antenna exit were evaluated for 32 fish (Table 21). Incisions or antenna exits were found to be in fair or poor condition for 12 (38%) of the recaptures, indicating some degree of long-term effect. Four (13%) of these recaptures had incisions or antenna exits in poor condition. It is not known how this condition affected behavior or fitness of the fish. One fish recaptured four times showed improvement in the condition of the antenna exit from fair to good between the first and second recaptures indicating that fish were able to recover from at least mild infections.

Weight change and condition factor (Kn) of recaptures were also used as indicators of effects of radio implanting on humpback chub. Weight change was calculated for 30 of the recaptured radio-tagged fish (Table 21). Weight decreased for 26 (87%) of these fish between the time of implant and recapture. Weight loss ranged from 1.6% (9 g) to 38% (304 g) of total initial weight. Weight gain was observed in four recaptures and ranged from 0.2% (1 g) to 6.9% (42 g) of initial weight. One radio-tagged fish recaptured four times over a period of 969 days had lost 38% (304 g) of its original weight between the time of release and first recapture. This was the largest weight loss observed for a recaptured radio-tagged fish. This fish subsequently gained 78 g during the time between the next recapture and 53 g when recaptured a third time indicating that recovery was possible, even after a large initial weight loss.

Weight change was compared to humpback chub that were not radio-tagged and captured during the same trip. Condition factor (Kn) of 32 recaptured radio-tagged fish was compared to a composite condition factor for humpback chub of similar size captured during the same trip (Table 22). Condition factor of 10 (31%) recaptured radio-tagged fish was below the 95% confidence interval of the composite condition factor for the corresponding trip, 14 (44%) were within the interval, and eight (25%) were above. Of the six fish that experienced an abnormally large weight loss (greater than 20% of initial weight) three had condition factors below the 95% C.I. of the composite, two were within, and one was above. Lack of a consistent trend between condition factors of radio-tagged fish and other humpback chub indicates high variability between individuals rather than a general affect to all fish. Based on relative condition, approximately 30% of humpback chub implanted with radio transmitters showed some adverse long-term affects from the technique.

Ranked indicators of overall condition of recaptured radio-tagged fish indicated that techniques that utilized the sheathed needle to exert the antenna (i.e., SNAG) resulted in less injury to fish than techniques that utilized mosquito forceps (Table 23). Condition of both the primary incision and antenna exit were consistently good (rank=3) for both techniques that utilized the sheathed needle. The rankings were less consistent for techniques utilizing mosquito forceps, especially condition of the antenna exit, which averaged only fair (rank=2) for 14 recaptures.

Differences between suture material (i.e., non-absorbable Gortex® versus absorbable Maxon®) could not be adequately evaluated because of limited sample size and compounding variables. Possibly, problems originally attributed to Gortex® sutures may have been associated with the antenna exertion technique. Fair to poor condition of the antenna exit associated with the mosquito forceps exertion technique appeared to be the major cause of infection rather than wicking of bacteria by the Gortex® sutures. Incision site (midline versus lateral) did not appear to affect overall condition of recaptured radio-tagged fish.

Stomach Pumping

Short-Term Effects

In September, 1992, one adult humpback chub (406 mm TL) died following the stomach pumping procedure. The fish had failed to expulse food from the vent or mouth following several injections of water into the gut and the procedure was halted. The fish appeared stressed and showed little sign of movement. The fish died after 1 hr. A post-mortem dissection revealed an unusual blockage of the lower intestine by a large seed ingested by the fish. Following the incident, all chubs processed with the stomach pump were lightly anesthetized with MS-222 to reduce the risk of a gag reflex preventing the backflushing of water in the event of intestinal blockage. Also, if a fish did not expulse food remains after two gentle flushes, the procedure was halted, termed 'unsuccessful', and the fish was released immediately. Of 168 humpback chub processed with the stomach pump, none showed signs of stress following pumping.

The stomach pumping technique had an interesting side-effect on humpback chub that may be considered beneficial. Most stomach pumped fish required less attention upon release than non-pumped fish. The technique seemed to expulse air from the gut of the fish that was apparently swallowed during processing, hence giving pumped fish greater equilibrium. Alternately, the abdomen of humpback chub was gently massaged to expel trapped air and enhance equilibrium. Stomach pumping also expulsed Asian tapeworms (Bothriocephalus acheilognathi) from the guts of 6 (3.6%) processed chubs. The efficiency of this technique for expelling the worms was not evaluated.

Long-Term Effects

The potential of latent mortality or harm to stomach-pumped humpback chub was evaluated by examining recapture information. Of 168 adult humpback chub processed with the stomach pump, 15 were subsequently recaptured (Table 24). Average number of days at large, change in RM captured, and change in weight of recaptured fish was 167 days (range, 5-492 days), 0.7 miles (range, -1.15-3.85 miles), and -39 g (range, -193- 44 g), respectively. The range of movement of stomach-pumped humpback chub was within the typical range of movement of non-pumped PIT-tagged individuals.

Although humpback chub lost an average of 39 g in weight between pumping and recapture, this weight loss was attributed to the timing of processing and recapture, rather than indicative of long-term harm inflicted by the stomach pump. Ten of 15 humpback chub were processed with the stomach pump between the months of March and April, the period just prior to spawning. Twelve of 15 recaptures occurred between May and September, following spawning. When compared to non-pumped humpback chub captured during the same sampling trip: 2 of 14 stomach-pumped chub had K-factors which fell within the 95% confidence interval (C.I.) of non-pumped chub; 5 had K-factors higher than the C.I.; and, 7 had K-factors lower than the C.I. (Table 25). These data suggest that stomach pumping had a variable effect on humpback chub.

DISCUSSION AND RECOMMENDATIONS

Distribution of Sampling

Spatial Stratification

The stratified random sampling design used in this investigation is one of the most effective means for sampling fishes in large rivers such as the Colorado River. A similar approach was used by Tyus et al. (1982) and Valdez et al. (1982) in assessing distribution and abundance of native fishes in the upper Colorado River basin. The system of spatial stratification forced biologists to sample some areas of the river that may not otherwise be sampled. This system also distributed sampling approximately evenly for given habitat complexes in order to evaluate habitat availability and use.

Stratification of the Colorado River by geomorphic reaches for the purpose of ichthyofaunal surveys is recommended, particularly for canyon regions. This partitioning distributes sampling by major habitat assemblages and reduces variability in catch data for spatial and temporal comparisons. This system of stratification also facilitates integration with other disciplines such as geology, geomorphology, beach dynamics, and riparian vegetation on a Geographic Information System (GIS).

Further division of geomorphic reaches into longitudinal sampling strata is also recommended. Most geomorphic reaches were too large to effectively sample, so a subsampling approach is recommended with strata of sufficient size to represent habitat assemblages in the reach and small enough to effectively sample with available time, gear, and personnel.

With large steep-gradient rivers like the Colorado River, sampling equally with all gears can be difficult because of shoreline configuration, swiftness, rapids, etc. Hence, it is unreasonable to expect an equal distribution of sampling by all gears for all sample strata and reaches, although a stratified sampling approach will maximize distribution of sampling.

Temporal Stratification

Sampling during different times of day and night is very important in characterizing fish assemblages in large rivers. Many fish are active and available to sampling gears primarily at night or during crepuscular periods (i.e., dawn, dusk), although their activity may be sustained during daylight hours during spawning periods. Hence, surveys for presence or absence of species, as well as estimates of abundance, require sampling during times when fish are most susceptible to capture. Sampling for fish at night must be balanced with crew fatigue, experience, and safety considerations.

Stratification of each 24-hr period into four time blocks is recommended for initial surveys to locate fish aggregations or to characterize diel activity. However, crew fatigue alone will dictate less sampling at night. The temporal stratification scheme used in this investigation worked well in that more sampling was conducted at night than might have been otherwise performed. Since day length and photoperiod varied with season, use of the computer program Sun and Moon Events Worksheet (Heizer Software, Inc., Palo Alto, CA) worked well for adjustments to blocks. The designated time blocks of day (sunrise to sunset), dusk (sunset to 2 hr after sunset), night (2 hr after sunset to 2 hr before sunrise), and dawn (2 hr before sunrise to sunrise) effectively partitioned those periods in which fish activity differed most.

Stratification of sampling by season is also recommended, although designated time periods can vary with region of the country. Sampling during winter and spring runoff is strongly recommended in large rivers, since these periods are typically undersampled during most investigations.

Sampling Gear Efficiency

The most efficient gear types for catching adult humpback chub (>200 mm TL) were short (50-ft) trammel nets with 1.0 or 1.5-in mesh. Longer trammel nets (75-ft) with 1.0 and 1.5-in mesh yielded more fish but at a lower catch rate. There did not appear to be a significant difference in catch rates of humpback chub between 1.0 and 1.5-in mesh.

The largest numbers of subadults (<200 mm TL, i.e., juveniles and YOY) were caught with electrofishing. This gear did not appear to injure significant numbers of native fishes; the rate of injury was higher for the trout species (1.0%) than for humpback chub (0.3%). Electrofishing is an effective gear for surveying young humpback chub along shorelines in canyon regions, since these areas are not easily sampled with other gears. However, electrofishing catch data can be highly variable because of gear efficiency and personnel experience.

Large numbers of subadult humpback chub were also captured with 0.25-in mesh seines, but the areas available to sampling were limited to sand beach faces and backwaters. Most rocky or vegetated shorelines could not be sampled with seines.

Perhaps the most effective and reliable gear for sampling subadult humpback chub was minnow traps. These were equally effective in all shoreline types, and seemed to reflect densities of fish in the area. Setting and retrieving the traps was relatively labor-efficient, and setting the traps in pods of five facilitated statistical analyses of catch rates.

It appears that the most effective gears for catching humpback chub were 1.0 and 1.5-in trammel nets (50 and 75-ft) for adults, minnow traps in all shoreline types for subadults, and 0.25-in mesh seines for subadults in backwaters and along beach faces.

Marking Techniques

PIT Tags

PIT tags are currently the most effective marking technique for the fishes of the Colorado River (Burdick and Hamman 1993). The tags appear to be relatively safe for the fish, they provide large storage capability for information on individual fish, they appear to last a long time, and they provide unique alpha-numeric identifiers for all fish. The major drawback to PIT tags is that they are not suitable for marking fish smaller than about 150 mm TL, and most investigators feel that 175 mm TL should be the minimum size of fish to be tagged (Burdick and Hamman 1993).

Continued use of PIT tags is recommended for native fishes in the Grand Canyon area, but investigators are strongly urged to provide quality training for personnel in the proper techniques for injection, scanning, and data storage. Fish that were suspected of shedding PIT tags during this investigation had apparently been improperly tagged. The most common problem was failure to inject the tag sufficiently deep into the body cavity; some tags were left beneath the skin where they were quickly shed.

Another common problem was a failure to properly use the PIT-tag scanners, and some tags numbers were unrecorded. Also, the scanners were varied in their ability to detect the PIT tags, and some tags could not be identified. It appeared that the Destron scanner at 400 KHz wavelength was more sensitive and tags were detected more easily and quickly than with the AVID scanner at 125-400 Khz wavelength.

Fin Punches
Fin punches seemed to work well for marking small numbers of subadult humpback chub for short time periods. The process was time consuming and stressed the fish particularly during warm summer months. The small numbers of fish recaptured with fin punches indicates that large numbers would have to be fin-punched to mark sufficient numbers for reasonable probability of recapture. Furthermore, loss of punch identity was not evaluated, but it appeared that fin regeneration was rapid, although ray distortion seemed to persist for some time.

There continues to be a need for unique marking of individual subadult humpback chub (<150 mm TL). There also is a need to develop batch marks. These marking techniques are needed for mark-recapture estimates of subadults in the system, as well as to determine survival rates and movement.

Radiotelemetry
Radiotelemetry was a very valuable tool for characterizing movement and behavior of adult humpback chub in Grand Canyon. While the ultimate fate of the 75 adults that were radio-tagged over 36 months was not determined, known mortality of 1 of 75 fish (1.3%) was considered acceptable for the volume and value of data generated on movement, habitat use, and behavior relative to Glen Canyon Dam operations. We believe that the majority of these radio-tagged adults survived beyond the investigative period. Humpback chub radio-tagged in 1980 by Valdez and Nilson (1982) were recaptured in 1984 by Kaeding et al. (1990) with incisions completely healed and in good condition.

Caution is advised in future radiotelemetry studies with humpback chub, or other native Colorado River fishes. The procedure requires a large investment of time and personnel to adequately track and monitor the fish to fully understand the implications of radiotelemetry data. Less than a concerted effort is an injustice to the possible sacrifice of fishes, and can lead to erroneous conclusions.

Where possible, internal antenna transmitters are advised, but where water conductivity and depth require external antenna transmitters, surgical procedures must be particularly meticulous to reduce the possibility of infection to incisions. A lateral primary incision is recommended and there should be no incision associated with the antenna exit; the antenna should be passed through the abdominal wall to allow it to seal around the cable. The SNAG device (sheathed needle antenna guide) was effective at reducing infection in this investigation. Maxon absorbable suture are recommended instead of Gortex nonabsorbable sutures, in order to enhance healing, reduce invasion by external bacteria, and minimize dehiscence.

Stomach Pumping
The stomach pumping method developed for this investigation provided valuable information on the food habits of adult humpback chub. Only one fish died as a direct result of stomach pumping, probably from intestinal blockage by a large seed previously ingested by the fish. Caution is recommended in using this or any other stomach evacuation techniques. Only experienced personnel should use the procedure, since the amount of pressure exerted by the stomach pump can be critical to the success of the procedure and to the eventual health of the fish.

Table 1. Proportion of sampling efforts by season.

Season	Percentage of Year[a]	Percentage (and total) Sampling Effort			
		Nets (hr)	Traps (hr)	Seine (M^2)	Electrofishing (hr)
Spring (March-May)	25	36% (8,200)	27% (22,338)	42% (49,075)	30% (233)
Summer (June-August)	25	18% (4,085)	32% (26,955)	9% (10, 417)	24% (190)
Fall (Sept.-Nov.)	31	27% (6,012)	34% (28,651)	37% (43,379)	32% (248)
Winter (Dec.-Feb)	19	19% (4,235)	7% (5,292)	12% (14, 255)	14% (113)
Totals:	100	22,532 hr	83,236 hr	117,126 m^2	784 hr

[a] weighted by number of trips in each season
[b] based on total hours of effort for nets, traps, electrofishing, and square meters for seines.

Table 2. Proportion of diel sampling efforts in four time blocks for nets and electrofishing.

Time Block	Percentage of 24-hr period	Percentage (and total) Sampling Time (hr)[a]	
		Gill and Trammel Nets	Electrofishing
Night (1930-0430 hrs)	37.5	13.7% (3,087)	30.2% (236)
Dawn (0430-0730 hrs)	12.5	16.6% (3,740)	18.1% (142)
Day (0730-1630 hrs)	37.5	28.3% (6,377)	24.7% (194)
Dusk (1630-1930 hrs)	12.5	41.4% (9,328)	27.0% (212)
Totals:	100.0	100.0% (22,532 hr)	100.0% (784 hr)

[a]based on start of sampling effort.

Table 3. Diel distribution of sampling by study region for nets and electrofishing. n=number of samples.

	Region									
	0		I		II		III		Totals	
Time Block[a]	n	Time Elapsed (hr)	n	Time Elapsed (hr)	n	Time Elapsed (hr)	n	Time Elapsed (hr)	n	Time Elapsed (hr)
					Gill and Trammel Nets					
0001-0200	0	0	20	44.7	7	20.1	9	23.8	36	88.6
0201-0400	0	0	25	48.4	13	31.6	6	17.4	44	97.4
0401-0600	21	49.5	110	2,46.7	359	832.7	180	424.8	670	1,553.7
0601-0800	52	1,13.0	151	3,33.5	677	1,447.4	308	645.4	1,188	2,539.3
0801-1000	51	1,14.0	143	301.1	679	1,442.3	259	557.5	1,132	2,414.9
1001-1200	17	39.5	183	385.4	366	788.5	157	342.6	723	1,556.0
1201-1400	27	67.3	261	568.8	124	277.2	106	239.9	518	1,153.2
1401-1600	47	1,15.9	444	964.1	194	448.8	154	341.0	839	1,869.8
1601-1800	118	2,68.2	1,023	2,332.5	828	1,688.8	498	1,053.0	2,467	5,342.5
1801-2000	139	2,74.0	937	1,966.2	820	1,696.6	461	960.6	2,357	4,897.4
2001-2200	82	1,51.55	726	1,309.8	593	1,027.9	289	515.1	1,690	3,004.3
2201-2400	2	6.5	74	1,18.5	32	51.53	17	27.7	125	204.2
Totals	**556**	**119.4**	**4,097**	**7,448.9**	**4,693**	**9,753.4**	**2,444**	**5,148.8**	**11,989**	**27,721.3**
					Electrofishing					
0001-0200	1	0.1	2	0.2	2	0.8	1	0.2	6	1.3
0201-0400	0	0	1	0.2	0	0	0	0	1	0.2
0401-0600	16	3.3	115	24.1	33	12.4	19	6.0	167	45.8
0601-0800	29	5.6	233	47.2	313	111.9	114	37.4	689	202.1
0801-1000	10	3.1	94	36.1	214	71.5	63	25.3	381	136.0
1001-1200	13	1.9	140	25.0	132	38.8	51	16.5	336	82.2
1201-1400	6	0.7	94	19.5	34	9.4	21	3.8	155	33.4
1401-1600	27	5.1	247	59.5	44	13.8	28	8.1	346	86.5
1601-1800	28	6.1	173	38.8	156	58.4	34	14.3	391	117.6
1801-2000	42	6.9	346	78.2	342	117.9	148	56.9	878	253.0
2001-2200	64	12.9	580	201.3	330	119.7	135	45.5	1,109	379.4
2201-2400	10	1.4	93	20.5	28	9.4	6	0.9	137	32.2
Totals	**246**	**47.1**	**2118**	**550.6**	**1,628**	**564**	**620**	**214.9**	**4,596**	**1,369.7**

[a]Time block based on start of sampling period

Table 4. Description of fish sample gears and numbers of humpback chub captured in the Colorado River in Grand Canyon, October 1990 - November 1993.

Sample Gear Code-Description	Total No. Samples	Total Effort	Number of Chub[a] Y	J	A	T	Gross GM_{CPE}
Gill Nets		(Hours)					(#/100 ft/100 hr)
GP - 100'x6'x1.5" gill net	1,321	2,751	0	1	143	144	5.2
GM - 100'x6'x2" gill net	932	1,945	0	0	65	65	3.3
GX - Experimental gill net, 100'	509	1,061	0	45	51	96	9.0
GZ - Experimental gill net, 60'	30	59	0	0	0	0	0
Trammel Nets							
TL - 75'x6'x1.5"x12" trammel net	3,235	6,774	0	2	586	588	11.6
TK - 75'x6'x1"x12" trammel net	3,229	6,734	0	33	553	586	11.6
TM - 50'x6'x1"x12" trammel net	747	1,550	0	12	107	119	15.4
TN - 50'x6'x1.5"x12" trammel net	767	1,599	0	0	119	119	14.9
TW - 75'x6'x0.5"x10" trammel net	22	43	0	0	0	0	0
TY - Floating TK	6	11	0	0	3	3	36.0
TZ - Floating TL	3	5	0	0	1	1	25.6
Hoop Nets							(#/100 hr)
HL - Large hoop net (4'x16'x1")	63	910	1	1	2	4	0.4
HM - Medium hoop net (3'x13'x1")	17	270	0	0	0	0	0
HS - Small hoop net (2'x10'x0.5")	86	1,369	0	0	2	2	0.1
Minnow Traps							
MT - Commercial minnow trap	4,562	85,111	629	298	0	927	1.1
Electrofishing							(#/10 hr)
EL - 220-V DC	2,886	784	1,272	767	138	2,177	27.8
Seines		(Square Meters)					(#/100 m^2)
SA - 10'x3'x0.125" seine	113	15,672	90	51	0	141	0.9
SB - 30'x4'x0.25" seine	83	10,562	135	42	2	179	1.7
SG - 30'x5'x0.25" seine	328	59,057	705	351	9	1,065	1.8
GF - Floated gill net	6	1,350	0	0	2	2	0.1
TF - Floated trammel net	2	22,500	0	0	0	0	0
Misc. qualitative seine hauls	83	-	33	35	5	73	-
Angling[b]							
AN - standard gear, bait	2	-	0	0	2	2	-
AL - standard gear, lures, artificials	4	-	0	0	1	1	-
Total	**19,036**	**-**	**2,865**	**1,638**	**1,791**	**6,294**	

[a]Y = young-of-year, J = juvenile, A = adult, T = total.
[b]no effort recorded

Table 5. Total sample effort and arithmetic mean catch rate (AMcpe) of adult, juvenile and YOY humpback chub by gear in the four study regions.

GEAR[a]	Total samples (Total time - hr) REGION 0	I	II	III	AMcpe (number of fish) Adult HB REACH 0	I	II	III	Juvenile HB REGION 0	I	II	III	YOY HB REGION 0	I	II	III
GILL AND TRAMMEL NETS[b]																
GM	63 (134.4)	378 (791.8)	298 (604.8)	193 (414.1)	0	8.1 (64)	0.12 (1)	0	0	0	0	0	0	0	0	0
GP	56 (119.4)	477 (1006.0)	507 (1030.1)	281 (595.7)	1.17 (1)	14.4 (139)	0.3 (3)	0	0	0.1 (1)	0	0	0	0	0	0
GX	0	180 (374.1)	174 (368.0)	155 (318.5)	-	15.7 (47)	1.6 (4)	0	-	11.1 (44)	0.4 (1)	0	-	0	0	0
GZ	0	0	16 (31.4)	14 (27.2)	-	-	0	0	-	-	0	0	-	-	0	0
TK	174 (371.7)	989 (2060.0)	1263 (2634.9)	803 (1667.0)	1.91 (6)	32.2 (468)	3.4 (75)	0.25 (3)	0	1.8 (28)	0.4 (8)	0	0	0	0	0
TL	137 (295.6)	1044 (2165.1)	1386 (2876.3)	668 (1436.7)	4.2 (8)	32.6 (533)	8.8 (39)	0.5 (6)	0	0.1 (2)	0	0	0	0	0	0
TM	49 (110.7)	189 (393.0)	390 (803.3)	119 (243.3)	9.2 (5)	35.5 (63)	10.0 (37)	1.6 (2)	0	5.5 (9)	0.7 (3)	0	0	0	0	0
TN	43 (92.8)	175 (362.9)	410 (858.6)	139 (285.1)	7.8 (4)	55.3 (103)	2.9 (12)	0	0	0	0	0	0	0	0	0
TW	8 (15.7)	3 (6.1)	11 (21.5)	0	0	0	0	-	0	0	0	-	0	0	0	-
TY	0	6 (11.1)	0	0	-	43.8 (3)	-	-	-	0	-	-	-	0	-	-
TZ	0	3 (5.2)	0	0	-	24.4 (1)	-	-	-	0	-	-	-	0	-	-
Total	530 (1140.3)	3444 (7175.3)	4455 (9228.9)	2372 (4987.6)												
MINNOW TRAPS AND HOOP NETS[c]																
HL	0	4 (37.1)	40 (687.5)	19 (316.1)	-	5.6 (2)	0	0	-	0	0.1 (1)	0	-	0	0.1 (1)	0
HM	0	2 (38.8)	13 (191.3)	2 (39.3)	-	0	0	0	-	0	0	0	-	0	0	0
HS	0	4 (30.8)	73 (1187.6)	9 (150.4)	-	2.0 (1)	0.63 (1)	0	-	0	0	0	-	0	0	0
MT	12 (210.3)	3847 (65866.7)	622 (12752.2)	81 (1721.2)	0	0	0	0	0	0.5 (271)	0.2 2 (10)	0	0	1.14 (638)	0.13 (9)	0
Total	12 (210.3)	3857 (65973.4)	748 (14818.6)	111 (2227.0)												
SEINES[d]																
		(area m²)														
SA	0	42 (7000.0)	54 (5983.4)	17 (2689.0)	-	0	0	0	-	4.3 (45)	0.3 (6)	0	-	6.8 (72)	1.6 (18)	0
SB	13 (779.0)	48 (6605.5)	19 (2901.0)	3 (276.0)	0	0.1 (2)	0	0	0	1.2 (42)	0	0	0	2.7 (135)	0	0
GF	0	6 (1350.0)	0	0	-	0.1 (2)	-	-	-	0	-	-	-	0	-	-
SG	1 (60.0)	297 (53748.0)	15 (1789.0)	15 (3460.0)	0	0.03 (9)	0	0	0	2.1 (346)	0.1 (3)	0.1 (2)	0	4.1 (704)	0.03 (1)	0
TF	0	0	0	2 (22500.0)	-	-	-	0	-	-	-	0	-	-	-	0
Qual	5	46	21	11	-	-	-	-	-	-	-	-	-	-	-	-
Total	19 (839.0)	439 (68703.5)	109 (10673.4)	50 (28925.0)												
ELECTROFISHING[e]																
EL	217 (40.8)	1319 (308.5)	909 (293.4)	441 (141.0)	0.43 (2)	5.8 (125)	0.5 (9)	0.1 (1)	0	24.9 (742)	0.4 (11)	0	0	55.1 (1283)	0.1 (3)	0
ANGLING[f]																
AL	-	-	-	-	-	- (2)	-	-	-	-	-	-	-	-	-	-
AN	-	-	-	-	-	- (1)	-	-	-	-	-	-	-	-	-	-

[a]See Table 5-1 for gear codes.
[b]CPE = fish/100 ft/100 hr
[c]CPE = fish/100 hr
[d]CPE = fish/100 m²
[e]CPE = fish/10 hr
[f]no effort recorded

Table 6. Arithmetic mean catch rate (AMcpe) of adult, juvenile and YOY flannelmouth sucker by gear in the Colorado River in Grand Canyon, October 1990-November 1993.

GEAR[a]	Total samples (Total time - hr) REGION 0	I	II	III	AMcpe (number of fish) Adult FM REGION 0	I	II	III	Juvenile FM REGION 0	I	II	III	YOY FM REGION 0	I	II	III
							NETS[b]									
GM	63 (134.4)	378 (791.8)	298 (604.8)	193 (414.1)	0.7 (1)	14.2 (113)	2.9 (18)	0	0	0	0	0	0	0	0	0
GP	56 (119.4)	477 (1006.0)	507 (1030.1)	281 (595.7)	0	5.7 (60)	2.1 (23)	1.5 (8)	0	0	0	0	0	0	0	0
GX	0	180 (374.1)	174 (368.0)	155 (318.5)	-	14.7 (49)	0.3 (1)	2.6 (9)	-	0.3 (1)	0	0.3 (1)	-	0	0	0
GZ	0	0	16 (31.4)	14 (27.2)	-	-	0	0	-	-	0	0	-	-	0	0
TK	174 (371.7)	989 (2060.0)	1263 (2634.9)	803 (1667.0)	1.6 (4)	14.1 (206)	8.5 (173)	5.2 (65)	0	0	0.1 (1)	0	0	0	0	0
TL	137 (295.6)	1044 (2165.1)	1386 (2876.3)	668 (1436.7)	4.8 (8)	22.5 (378)	10.5 (223)	3.1 (32)	0	0	0	0	0	0	0	0
TM	49 (110.7)	189 (393.0)	390 (803.3)	119 (243.3)	8.8 (5)	10.1 (21)	14.2 (61)	30.5 (38)	0	0	0	0	0	0	0	0
TN	43 (92.8)	175 (362.9)	410 (858.6)	139 (285.1)	4.1 (2)	36.5 (69)	16.4 (72)	30.2 (47)	0	0	0	0	0	0	0	0
TW	8 (15.7)	3 (6.1)	11 (21.5)	0	0	0	0	-	-	-	0	0	-	-	0	0
TY	0	6 (11.1)	0	0	-	27.4 (2)	-	-	-	0	-	-	-	0	-	-
TZ	0	3 (5.2)	0	0	-	20.2 (1)	-	-	-	0	-	-	-	0	-	-
Totals	530 (1140.3)	3444 (7175.3)	4455 (9228.9)	2372 (4987.6)												
							TRAPS[c]									
HL	0	4 (37.1)	40 (687.5)	19 (316.1)	-	0	19.1 (162)	17.6 (48)	-	0	1.9 (16)	0.7 (3)	-	0	0	0
HM	0	2 (38.8)	13 (191.3)	2 (39.3)	-	0	0	0	-	0	0	0	-	0	0	0
HS	0	4 (30.8)	73 (1187.6)	9 (150.4)	-	0	0.8 (10)	6.6 (10)	-	0	2.1 (30)	2.8 (4)	-	0	0	0
MT	12 (210.3)	3847 (65866.7)	622 (12752.2)	81 (1721.2)	0	0	0	0	0	0.01 (5)	0.2 (16)	0.1 (1)	0	0	0	0
Totals	12 (210.3)	3857 (65973.4)	748 (14816.6)	111 (2227.0)												
							SEINES[e]									
		(area m²)														
SA	0	42 (7000.0)	54 (5983.4)	17 (2689.0)	-	0	0.2 (9)	0	0	0.6 (7)	0.3 (12)	0.7 (5)	-	0.4 (5)	0	1.3 (3)
SB	13 (779.0)	48 (6605.5)	19 (2901.0)	3 (276.0)	0	0	0	0	0	0.1 (6)	0.02 (1)	0	0	0.1 (6)	0	0
GF	0	6 (1350.0)	0	0	-	0.3 (4)	-	-	-	0	-	-	-	0	-	-
SG	1 (60.0)	297 (53748.0)	15 (1789.0)	15 (3460.0)	0	0.02 (7)	0	0.1 (1)	0	0.2 (86)	0.1 (1)	0.9 (31)	0	0.5 (85)	0	2.2 (13)
TF	0	0	0	2 (22500.0)	-	-	-	0	-	-	-	0	-	-	-	0
Qual	5	46	21	11	-	-	-	-	-	-	-	-	-	-	-	-
Total	19 (839.0)	439 (68703.5)	109 (10673.4)	50 (28925.0)												
							ELECTROFISHING[d]									
EL	217 (40.8)	1319 (308.5)	909 (293.4)	441 (141.0)	42.1 (44)	3.6 (80)	3.4 (72)	5.0 (50)	0	1.4 (42)	2.2 (52)	3.7 (46)	0	0.7 (19)	0.02 (1)	0.2 (1)

[a]See Table 4-1 for gear codes.
[b]CPE = fish/100 ft/100 hr
[c]CPE = fish/100 hr
[d]CPE = fish/10 hr
[e]CPE = fish/100 m²
[f]CPE = fish/10 hr

Table 7. Arithmetic mean catch rate (AMcpe) of adult, juvenile and YOY bluehead sucker by gear in the Colorado River in Grand Canyon, October 1990-November 1993.

GEAR[a]	Total samples (Total time - hr) REGION				AMcpe (number of fish) Adult BH REGION				Juvenile BH REGION				YOY BH REGION			
	0	I	II	III	0	I	II	III	0	I	II	III	0	I	II	III
							NETS[b]									
GM	63 (134.4)	378 (791.8)	298 (604.8)	193 (414.1)	0	0	0.2 (1)	0	0	0	0	0	0	0	0	0
GP	56 (119.4)	477 (1006.0)	507 (1030.1)	281 (595.7)	0	0.6 (6)	0.3 (3)	0.5 (3)	0	0	0	0	0	0	0	0
GX	0	180 (374.1)	174 (368.0)	155 (318.5)	-	2.7 (7)	0.2 (1)	0.7 (2)	-	0	0	0	-	0	0	0
GZ	0	0	16 (31.4)	14 (27.2)	-	0	0	-	-	0	0	-	-	0	0	-
TK	174 (371.7)	989 (2060.0)	1263 (2634.9)	803 (1667.0)	0.3 (1)	5.2 (76)	3.1 (60)	2.0 (24)	0	0	0	0	0	0	0	0
TL	137 (295.6)	1044 (2165.1)	1386 (2876.3)	668 (1436.7)	0.6 (1)	1.1 (18)	1.1 (24)	0.9 (9)	0	0	0	0	0	0	0	0
TM	49 (110.7)	189 (393.0)	390 (803.3)	119 (243.3)	0	8.8 (17)	3.5 (14)	0.8 (1)	0	0	0	0	0	0	0	0
TN	43 (92.8)	175 (362.9)	410 (858.6)	139 (265.1)	0	3.5 (6)	0.8 (4)	8.6 (13)	0	0	0	0	0	0	0	0
TW	8 (15.7)	3 (6.1)	11 (21.5)	0	0	0	0	-	0	0	0	-	0	0	0	-
TY	0	6 (11.1)	0	0	-	0	-	-	-	0	-	-	-	0	-	-
TZ	0	3 (5.2)	0	0	-	0	-	-	-	0	-	-	-	0	-	-
Totals	**530 (1140.3)**	**3444 (7175.3)**	**4455 (9228.9)**	**2372 (4987.6)**												
							TRAPS[c]									
HL	0	4 (37.1)	40 (687.5)	19 (316.1)	-	7.0 (2)	4.6 (35)	18.9 (71)	-	0	0.4 (3)	0.9 (3)	-	0	0	0
HM	0	2 (38.8)	13 (191.3)	2 (39.3)	-	0	0	0	-	0	0	0	-	0	0	0
HS	0	4 (30.8)	73 (1167.6)	9 (150.4)	-	2.0 (1)	5.6 (73)	83.4 (148)	-	0	0.9 (13)	7.5 (14)	-	0	0	0
MT	12 (210.3)	3847 (65866.7)	622 (12752.2)	81 (1721.2)	0	0	0	0	0	0.001 (1)	0.1 (8)	0	0	0.001 (1)	0	0
Totals	**12 (210.3)**	**3857 (65973.4)**	**748 (14618.6)**	**111 (2227.0)**												
							SEINES[e]									
		(area m²)														
SA	0	42 (7000.0)	54 (5983.4)	17 (2689.0)	-	0	0.1 (2)	0	-	0.4 (4)	0.1 (3)	0.2 (3)	-	0.7 (12)	0.1 (3)	0.3 (2)
SB	13 (779.0)	48 (6605.5)	19 (2901.0)	3 (276.0)	0	0.02 (1)	0	0	0	0.3 (17)	0	0	0	0.8 (33)	0	0
GF	0	6 (1350.0)	0	0	-	0	-	-	-	0.1 (2)	-	-	-	0	-	-
SG	1 (60.0)	297 (53748.0)	15 (1789.0)	15 (3460.0)	0	0.03 (11)	0	0	0	0.4 (57)	0.2 (4)	1.5 (52)	0	0.2 (30)	0.1 (1)	0.6 (8)
TF	0	0	0	2 (22500.0)	-	-	-	0	-	-	-	0	-	-	-	0
Qual.	5	46	21	11	-	-	-	-	-	-	-	-	-	-	-	-
Total	**19 (839.0)**	**439 (68703.5)**	**109 (10673.4)**	**50 (28925.0)**												
							ELECTROFISHING[d]									
EL	217 (40.8)	1319 (308.5)	909 (293.4)	441 (141.0)	0	0.76 (12)	1.0 (24)	1.5 (17)	0	1.0 (26)	0.6 (17)	1.2 (15)	0	0.1 (3)	0.1 (5)	0.1 (1)

[a]See Table 4-1 for gear codes.
[b]CPE = fish/100 ft/100 hr
[c]CPE = fish/100 hr
[d]CPE = fish/10 hr
[e]CPE = fish/100 m²
[f]CPE = fish/10 hr

Table 8. Arithmetic mean catch rate (AMcpe) of adult, juvenile and YOY rainbow trout by gear in the Colorado River in Grand Canyon, October 1990-November 1993.

GEAR[a]	Total samples (Total time - hr) REGION 0	I	II	III	AMcpe (number of fish) Adult RB REGION 0	I	II	III	Juvenile RB REGION 0	I	II	III	YOY RB REGION 0	I	II	III
NETS[b]																
GM	63 (134.4)	378 (791.8)	298 (604.8)	193 (414.1)	1.3 (2)	6.0 (39)	0.3 (2)	0	0	0	0	0	0	0	0	0
GP	56 (119.4)	477 (1006.0)	507 (1030.1)	281 (595.7)	54.0 (66)	38.0 (383)	5.0 (47)	0.8 (5)	0	0	0	0	0	0	0	0
GX	0	180 (374.1)	174 (368.0)	155 (318.5)	-	16.6 (51)	4.2 (13)	1.9 (6)	-	0.3 (1)	0	0.7 (2)	-	0	0	0
GZ	0	0	16 (31.4)	14 (27.2)	-	-	0	0	-	-	0	0	-	-	0	0
TK	174 (371.7)	989 (2060.0)	1263 (2634.9)	803 (1667.0)	79.7 (214)	22.6 (317)	8.3 (160)	1.5 (19)	0.8 (2)	0.1 (1)	0.1 (1)	0	0	0	0	0
TL	137 (295.6)	1044 (2165.1)	1386 (2876.3)	668 (1436.7)	101.7 (222)	47.0 (741)	3.4 (68)	1.3 (13)	0	0.1 (1)	0.1 (1)	0.1 (1)	0	0	0	0
TM	49 (110.7)	189 (393.0)	390 (803.3)	119 (243.3)	175.5 (107)	15.0 (27)	13.4 (49)	1.7 (2)	0	0	0	0	0	0	0	0
TN	43 (92.8)	175 (362.9)	410 (858.6)	139 (285.1)	173.1 (85)	42.3 (75)	4.4 (20)	0	0	0	0	0	0	0	0	0
TW	8 (15.7)	3 (6.1)	11 (21.5)	0	0	0	0	-	0	0	0	-	0	0	0	-
TY	0	6 (11.1)	0	0	-	82.0 (7)	-	-	-	0	-	-	-	0	-	-
TZ	0	3 (5.2)	0	0	-	0	-	-	-	0	-	-	-	0	-	-
Totals	530 (1140.3)	3444 (7175.3)	4455 (9228.9)	2372 (4987.6)												
TRAPS[c]																
HL	0	4 (37.1)	40 (687.5)	19 (316.1)	-	0	7.8 (39)	1.6 (5)	-	0	0.4 (3)	0.5 (2)	-	0	0	0
HM	0	2 (38.8)	13 (191.3)	2 (39.3)	-	0	15.8 (35)	0	-	0	5.7 (3)	0	-	0	0	0
HS	0	4 (30.8)	73 (1187.6)	9 (150.4)	-	0	9.8 (102)	0	-	0	1.3 (14)	0	-	0	0	0
MT	12 (210.3)	3847 (65866.7)	622 (12752.2)	81 (1721.2)	0	0	0	0	0	0.01 (6)	0.01 (2)	0	0	0.02 (7)	0.05 (8)	0
Totals	12 (210.3)	3857 (65973.4)	748 (14818.6)	111 (2227.0)												
SEINES[e]																
		(area m²)														
SA	0	42 (7000.0)	54 (5983.4)	17 (2689.0)	-	0.02 (1)	0.02 (5)	0.1 (1)	-	0	0.1 (5)	0	-	0	2.3 (34)	0
SB	13 (779.0)	48 (6605.5)	19 (2901.0)	3 (276.0)	1.1 (2)	0.2 (5)	0.4 (6)	0	0.6 (6)	0.1 (5)	0.2 (6)	0	0	0	0	0
GF	0	6 (1350.0)	0	0	-	0.1 (1)	-	-	-	0	-	-	-	0	-	-
SG	1 (60.0)	297 (53748.0)	15 (1789.0)	15 (3460.0)	0	0.2 (67)	0	0	0	0.02 (7)	0.04 (2)	0	0	0.01 (1)	0	0
TF	0	0	0	2 (22500.0)	-	-	-	0	-	-	-	0	-	-	-	0
Qual	5	46	21	11	-	-	-	-	-	-	-	-	-	-	-	-
Total	19 (839.0)	439 (68703.5)	109 (10673.4)	50 (28925.0)												
ELECTROFISHING[d]																
EL	217 (40.8)	1319 (308.5)	909 (293.4)	441 (141.0)	343.8 (1314)	123.1 (3423)	86.1 (1981)	4.4 (61)	88.3 (283)	14.3 (391)	12.9 (348)	3.7 (58)	9.7 (34)	1.9 (47)	0.9 (30)	0.3 (7)
ANGLING																
AN	0	2 (1.7)	0	0	-	0	-	-	-	0	-	-	-	0	-	-
AL	0	4 (4.5)	0	0	-	216.7 (8)	-	-	-	0	-	-	-	0	-	-
Totals	0	6 (6.2)	0	0												

[a]See Table 4-1 for gear codes
[b]CPE = fish/100 ft/100 hr
[c]CPE = fish/100 hr
[d]CPE = fish/10 hr
[e]CPE = fish/100 m²
[f]CPE = fish/10 hr

Table 9. Number of fish species captured by 21 gear types. See Table 4 for gear codes.

	Fish Species[a]																
	BB	BH	BK	BR	CC	CP	FH	FM	FR	GS	HB	PK	RB	SB	SD	SU	WE
AN[b]											3		5				
EL	4	120	4	1,390	10	1,986	352	407	5	3	2,176	6	7,977	19	508	4	
GF		2			1	2		4			2		1				
GM		1		14	1	10		132	2		65		43				
GP		12	1	26	5	17		91			144		501				
GX		10		1	2	7		61	1		96		73				
GZ									1								
HL		114	1	2		4	2	229			4		49		34		
HM				1									38				
HS	1	249		7		2		54			2		116		27		
MT		10		1	1		75	22			928	10	23		279		
SA		39		2		7	113	125			148	55	48		203	27	
SB		51					20	15			179		30		38		
SG		164		1	3	4	568	227			1,127	5	81		401	1	
TF						2					4		3				
TK	1	161		98	28	151		449	3		586		714	11	1		1
TL		52		74	61	156		641	4		588		1,047	9			
TM		32		30	1	33		125	1		119		185	1			
TN		23		25		42		190	6		119		180				
TY								2			3		7				
TZ								1			1						
Total	6.00	1,040.00	6.00	1,672.00	113.00	2,423.00	1,130.00	2,775.00	23.00	3.00	6,294.00	76.00	11,121.00	40.00	1,491.00	32.00	1.00

[a]BB = black bullhead
BH = bluehead sucker
BK = brook trout
BR = brown trout
CC = channel catfish
CP = common carp
FH = fathead minnow
FM = flannelmouth sucker
FR = flannelmouth x razorback hybrid
GS = green sunfish
HB = humpback chub
PK = plains killifish
RB = rainbow trout
SB = striped bass
SD = speckled dace
SU = unidentified sucker
WE = walleye

[b]Does not include all rainbow trout captured angling, only those recorded.

Table 10. Summary of humpback chub captured and marked by year by BIO/WEST, October 1990-November 1993.

Year	Age	No. Captured	No. Tagged		No. Fin Punched		Total Marks
			PIT	Radio[1]	Dorsal	Caudal	
1990	Adult	93	69	17	-	-	69
	Juvenile	3	-	-	-	-	-
	YOY	0	-	-	-	-	-
1991	Adult	515	350	36	-	-	350
	Juvenile	238	15	-	-	5	20
	YOY	117	-	-	-	2	2
1992	Adult	422	212	22	-	-	212
	Juvenile	527	41	-	13	10	64
	YOY	119	-	-	16	4	20
1993	Adult	2,629	224	3	-	-	224
	Juvenile	870	72	-	512	195	779
	YOY	761	-	-	259	47	306
Total		6,294	983	78	800	263	2,046

[1]Radiotagged fish are a subset of PIT tagged fish.

Table 11. Summary of humpback chub recaptured by BIO/WEST and other investigators by year, in the LCR and Colorado River, October 1990 - November 1993.

Trip	Age	No. PIT Tags		Radio tag[1]	No. Fin Marks		Other Tags		Total
		B/W	Other		Punch	Clip	Carlin Tag	Floy Tag	
1990	Adult	4	3	5	-	2	7	3	24
	Juvenile	-	-	-	-	-	-	-	-
	YOY	-	-	-	-	-	-	-	-
1991	Adult	61	42	12	1	1	26	19	162
	Juvenile	-	-	-	-	-	2	-	2
	YOY	-	-	-	-	-	-	-	-
1992	Adult	63	132	4	-	-	8	2	209
	Juvenile	-	8	-	-	10	2	-	20
	YOY	-	-	-	-	-	-	-	-
1993	Adult	151	374	2	-	-	4	3	534
	Juvenile	-	6	-	8	12	1	-	27
	YOY	-	-	-	3	1	-	-	4
Total		279	565	23	12	26	50	27	982

[1]Radiotagged fish are a subset of all tagged fish (including carlin, floy or PIT tags).

Table 12. Summary of flannelmouth sucker (FM), and bluehead sucker (BH) captured and PIT-tagged by year October 1990 - November 1993.

	No. Captured		No. PIT Tags	
Year	FM	BH	FM	BH
1990	53	5	0	0
1991	790	208	100	17
1992	731	233	431	144
1993	1,085	569	540	233
Totals	**2,659**	**1,015**	**1,071**	**394**

Table 13. Summary of flannelmouth sucker (FM), and bluehead sucker (BH) recaptured by year, October 1990 - November 1993.

		PIT tags							
		BIO/WEST			Others				
Year	Total Recaptured	FM	BH	Total	FM	BH	Total	Carlin Tag	Floy tag
1990	1	0	0	0	0	0	0	0	1
1991	25	5	0	5	8	0	8	0	12
1992	105	47	2	49	48	2	50	1	5
1993	313	124	11	135	163	10	173	0	5
Total	**444**	**176**	**13**	**189**	**219**	**12**	**231**	**1**	**23**

Table 14. Relative condition factor (Kn) for marked and recaptured humpback chub (TL > 150 mm) from the Colorado River, October 1990-November 1993.

Tag Type	Initial		Recapture	
	No. Fish	Kn	No. Fish	Kn
PIT	802	0.956	879	0.944
Carlin	26	0.894	26	1.032
Floy	24	0.855	24	1.028

Table 15. Recapture frequency, and length and weight change of PIT-tagged humpback chub captured by BIO/WEST and other agencies in Grand Canyon, October 1990 - November 1993.

Recapture Frequency	No. Fish	Total Length (mm)		Weight (g)	
		Change/30 days	St. Dev.	Change/30 days	St. Dev.
0	5679				
1	756	0.68	1.95	-0.33	13.78
2	372	0.73	2.63	-1.72	18.10
3	158	1.15	4.28	-0.39	16.83
4	65	1.40	3.20	2.65	20.57
5	43	1.01	1.84	2.42	11.22
6	15	1.29	1.45	-1.25	11.69
7	4	1.38	1.30	1.73	5.59
8	2	3.70	3.20	3.50	8.80
9	1	2.90	0	4.20	0

Table 16. Summary of humpback chub mortalities recorded by B/W in the Colorado River in Grand Canyon, October 1990 - November 1993.

PIT Tag No.	Date	Gear Type[a]	RM Capture	Cause of Death
	910717	T	61.40	Unknown - found dead in minnow trap
7F7D08186A	910516	N	61.30	Unknown - found floating in LCR
7F7E43193F	911115	E	68.00	Leaped from live-well during electrofishing
7F7F3F3626	910112	E	60.80	Infection from radiotag, died during observation
7F7F33211A	920509	N	61.50	Killed by non-staff personnel while removing from net
	920512	E	61.20	Leaped from live-well during electrofishing
7F7F0E2F10	920818	E	63.20	Sacrificed - spinal injury from electrofishing
7F7F1F1153	920910	N	58.30	Died following stomach pumping
	920918	N	126.10	Failed to see fish in fouled net during flood
	921109	T	63.10	Unknown - dead in minnow trap
	921109	T	63.10	Unknown - dead in minnow trap
	930416	N	63.70	Sacrificed - possible tapeworm infestation
	930713	E	75.25	Unknown - found dead in trammel net
	930818	T	63.90	Unknown - found dead in minnow trap
	930919	T	63.90	Unknown - found dead in minnow trap
	930919	T	63.90	Unknown - found dead in minnow trap
	931017	E	65.07	Leaped from live-well during electrofishing
	931017	S	63.70	Suffocated by mud during seining
	931109	T	63.06	Unknown - found dead in minnow trap

[a]T = minnow trap
N = nets
E = electrofishing
S = seine

Table 17. Mortality rates of selected fish species captured in five fish sampling gear types in the Colorado River in Grand Canyon, October 1990 - November 1993.

Species[a]	Gear Types														
	Nets			Hoop Nets			Minnow Traps			Seines			Electrofishing		
	No. Captured	No. Morts	%	No. Captured	No. Morts	%	No. Captured	No. Morts	%	No. Captured	No. Morts	%	No. Captured	No. Morts	%
HB	1,721	2	0.1	6	0	0	928	7	0.8	1,454	1	0.1	2,176	4	0.2
FM	1,696	3	0.2	283	1	0.4	22	1	9.1	367	1	0.3	407	1	0.2
BH	293	2	0.7	363	1	0.3	10	0	0	254	0	0	120	0	0
RB	2,754	148	5.4	203	1	0.5	23	0	0	159	1	0.6	7,977	39	0.5

[a]HB = humpback chub
FM = flannelmouth sucker
BH = bluehead suckers
RB = rainbow trout

Table 18. External morphological field observations of selected fish captured by electrofishing in the Colorado River in Grand Canyon, 1990-1991.

Species[a]	Total Captured	Effect of Electrofishing: Bruise Mark	Spinal Injury	Equilibrium Loss	Extended Narcosis	Unspecified	Total
RB	7,977	62	9	0	0	10	81
BR	1,390	2	0	0	0	4	6
HB	2,176	0	1	2	3	0	6
	11,543	64	10	2	3	14	93

[a]RB=rainbow trout
BR=brown trout
HB=humpback chub

Table 19. Mean relative condition factor (Kn) of adult humpback chub initially PIT-tagged by researchers in both the mainstem and LCR and recaptured in the mainstem Colorado River in Grand Canyon, October 1990 - November 1993.

No. of Times Recaptured	No. of Fish	Mean Kn	S.D. Kn
0	5,679	0.878	0.195
1	756	0.959	0.165
2	372	0.923	0.146
3	158	0.920	0.144
4	65	0.897	0.131
5	43	0.877	0.107
6	15	0.849	0.120
7	4	0.815	0.084
8	2	0.741	0.002
9	1	0.752	0

Table 20. Summary of surgical techniques used to implant radio transmitters in 75 humpback chub in Grand Canyon, October 1990 - November 1993.

Technique	No. of Fish	Incision Site	Suture Material	Antenna Extrusion Technique
MGM	31	Midline	Gortex (non-absorbable)	Mosquito forceps
MMM	7	Midline	Maxon (absorbable)	Mosquito forceps
MMS	19	Midline	Maxon (absorbable)	Sheathed needle
LMS	18	Lateral	Maxon (absorbable)	Sheathed needle

Table 21. Data and evaluation of condition for 34 radio-tagged adult humpback chub recaptured from the Colorado River in Grand Canyon, October 1990 - November 1993.

PIT Tag	Sex	Implant Release Date (ymd)	Recap Date (ymd)	# Days at large	RM Cap	RM Recap	Net Displac[1] (miles)	Original Weight (gm)	Recap Weight (gm)	Weight Change (%)	Surgical Procedure[2]	Condition[3] Primary Incision	Condition[3] Antenna Exit
7F7F3F3626	F	901017	910112	87	60.4	61.4	-1.0	780	713	-67(8.6)	MGM	poor	poor
7F7F456B2C	M	901020	910116	88	65.5	64.7	+0.8	605	544	-61(10.0)	MGM	fair	poor
7F7F3C4162	M	901123	910114	52	64.4	64.1	+0.3	732	681	-51(7.0)	MGM	good	fair
7F7F3F4E77	M	901117	910311	114	61.0	61.2	-0.2	675	649	-26(4.0)	MGM	fair	fair
7F7F3F520D	M	910311	910515	65	61.2	60.9	+0.3	604	565	-39(6.5)	MGM	good	fair
7F7F3C243E	M	910311	910612	93	61.2	60.9	+0.3	580	514	-66(11.0)	MGM	poor	poor
7F7F3E2F3A	F	901019	910708	169	64.6	127.0	-61.5	500	452	-52(9.2)	MGM	good	fair
7F7F3C6F15	M	910518	910914	119	61.4	64.7	-3.3	554	555	+1.0(0.2)	MGM	good	fair
7F7D075B05	F	910612	911110	151	60.2	60.8	-0.6	644	594	-50(8.0)	MMM	poor	fair
7F7F3E3C5C[4]	F	901118	910725	256	61.1	2.9km[5]	-2.1	798	494	-304(38)	MGM	no photo	no photo
7F7F3E3C5C	F	901118	911110	357	61.1	61.3	-0.2	798	572	-226(28.0)	MGM	good	fair
7F7F3E3C5C[4]	F	901118	930512	906	61.1	5.91km[5]	-3.9	798	565	-233(29.2)	MGM	good	good
7F7F3E3C5C	**F**	**901118**	**930716**	**969**	**61.1**	**61.2**	**-0.1**	**798**	**619**	**-179(22.4)**	**MGM**	**good**	**good**
7F7F3F3764	F	910914	911112	59	64.7	64.6	+0.1	639	604	-35(5.5)	LMS	good	good
7F7F3E3542	M	910915	911113	59	64.4	64.4	0.0	612	580	-32(5.0)	LMS	good	good
7F7D086032	F	910613	920113	214	61.1	60.7	+0.4	669	686	+17(2.5)	MMM	good	fair
7F7F475E72	M	920308	920410	33	61.5	61.5	0	633	591	-42(6.6)	MMS	good	good
7F7F475E72[4]	F	920308	920424	46	61.5	0.9km[5]	+0.7	633	561	-72(11.4)	MMS	good	good
7F7D140108	M	920114	920509	116	60.7	61.5	-0.8	728	655	-73(10.0)	LMS	good	good
7F7F321C62	M	920713	920912	61	61.2	60.2	+1.0	628	660	+32(5.1)	LMS	good	good
7F7F1F6A79	F	911109	930115	431	60.1	61.2	-1.1	605	647	+42(6.9)	MMS	good	good
7F7D4D7901[4]	F	-	930117			63.8	-	-	591	-	M--	good	good
7F7D073D4A	M	930319	930521	63	127.5	127.6	-0.1	874	854	-20(2.3)	MMS	good	good
7F7D073D4A	F	930319	930619	92	127.5	127.5	0	874	844	-30(3.4)	MMS	good	good
7F7F21741B[4]	M	911112	920330	139	64.8	0.9km[5]	+4.0	557	505	-52(9.3)	LMS	good	good
7F7F1E7A65[4]	F	920408	920623	76	61.75			843	721	-122(14.5)	LMS	good	good
7F7E4B1037[4]	F	920111	-		58.3			556	-	-	LMS	good	good
•	F	-	910616			0.4km[5]			405	-		poor	fair
7F7F3C303B[4]	F	901116	910331	136	60.1	0.0km[5]	-1.25	665	554	-111(16.7)	MGM	good	good
7F7D084C05[4]	F	910715	920424	284	59.9	3.65km[5]	-3.7	566	557	-9(1.6)	MMS	good	good
7F7E432514[4]	F	920113	920427	105	60.45	1.0km[5]	-1.5	959	765	-194(20.2)	MMS	good	poor
7F7F456D61[4]	F	911107	930512	548	58.8	5.91km[5]	-6.2	710	625	-85(12)	MMS	good	good
7F7F206B7B[4]	F	920909	930613	277	58.2	0.0km[5]	-3.1	760	509	-251(33.0)	MMS	good	good
Not Recorded[4]			930424			3.07km[5]			563			no photo	no photo

[1] (+) = upstream, (-) = downstream

[2] MGM = midline incision, CV3 Gortex nonabsorbable sutures, no needle guide.
MMM = midline incision, 3-0 Maxon absorbable sutures, no needle guide.
MMS = midline incision, 3-0 Maxon absorbable sutures, with SNAG needle guide.
LMS = lateral incision, 3-0 Maxon absorbable sutures, with SNAG needle guide.

[3] good - slight or no inflammation - healed/healing
fair - moderate inflammation/mild infection
poor - dehiscent incision or exit - infection present

[4] Recaptured by AGF or ASU

[5] recaptured in LCR

Table 22. Comparison condition factor (Kn) between recaptured radiotagged fish and other HB >369 mm TL captured during the same sampling trip in Grand Canyon, October 1990 - November 1993.

Condition Factor of Recap	Kn of pop. >369 mm (95% C.I.)	No. of fish > 369 mm	Relationship to C.I.	Percent Weight Change (%)
0.961	1.006-1.092	27	(-)	-8.6
0.975	1.006-1.092	27	(-)	-10.0
1.159	1.006-1.092	27	(+)	-7.0
1.027	0.928-1.064	20	(0)	-4.0
1.068	0.870-1.102	11	(0)	-6.5
1.041	0.892-1.001	19	(+)	-11.0
0.938	0.918-1.012	27	(0)	-9.2
0.980	0.969-1.084	32	(0)	+0.2
1.026	0.960-1.084	18	(0)	-8.0
0.918	0.960-1.084	18	(-)	-28.0
0.998	0.960-1.084	18	(0)	-5.5
1.055	0.960-1.084	18	(0)	-5.0
0.931	0.990-1.099	15	(-)	+2.5
1.013	0.529-1.592	3	(0)	-6.6
1.037	0.764-0.926	15	(+)	-10.0
0.933	0.960-1.112	21	(-)	+5.1
0.915	1.008-1.091	28	(-)	+6.9
1.391[a]	0.855-0.937	40	(+)	-2.3
1.524[a]	0.864-0.970	31	(+)	-3.4
0.987	0.904-0.967	30	(+)	-22.4
1.119[b]	0.529-1.592	3	(0)	-11.4
0.975[b]	1.008-1.118	15	(-)	-9.3
1.110[b]	0.806-0.906	16	(+)	-14.5
0.788[b]	0.918-1.012	35	(-)	-38
0.830[b]	0.892-1.001	20	(-)	-
0.948[b]	0.928-1.064	25	(0)	-16.7
0.901	0.529-1.592	3	(0)	-1.6
0.932	0.529-1.592	3	(0)	-20.2
0.894	0.855-0.937	40	(0)	-29.2
1.072	0.855-0.937	40	(+)	-12.0
0.794	0.864-0.970	31	(-)	-33.0
0.872	0.688-1.366	4	(0)	-

[a]Recaptured in Reach 2
[b]Recaptured in LCR

Table 23. Rankings of condition of recaptured radio-tagged humpback chub in Grand Canyon by surgical technique[1] used to implant fish. Factors ranked included relative condition factor (Kn), condition of primary incision, and condition of antenna exit.

	MGM				MMM				MMS				LMS			
	K[2]	I[3]	A[4]	T[5]	K	I	A	T	K	I	A	T	K	I	A	T
	0	1	1	2	1	1	2	3	1	3	3	7	1	3	3	7
	0	2	1	3	0	3	2	5	0	3	3	6	1	3	3	7
	2	3	2	7					2	3	3	8	2	3	3	8
	1	2	2	5					2	3	3	8	0	3	3	6
	1	3	2	6					1	3	3	7	0	3	3	6
	2	1	1	4					1	3	1	5	2	3	3	8
	1	3	2	6					2	3	3	8	-	3	3	-
	1	3	2	6					0	3	3	6				
	0	3	2	5					1	3	3	7				
	2	3	3	8												
	1	3	3	7												
	1	3	3	7												
x	1.0	2.5	2.0	5.5	0.5	2.0	2.0	4.0	1.1	3.0	2.7	6.8	1.0	3.0	3.0	7.0

[1]MGM = Midline incision, Gortex sutures, mosquito forceps.
MMM = Midline incision, Maxon sutures, mosquito forceps.
MMS = Midline incision, Maxon sutures, sheathed needle.
LMS = Lateral incision, Maxon sutures, sheathed needle.

[2]K = Relationship between Kn of radio-tagged fish and composite Kn for other humpback chub of similar size captured during the same trip.
Rankings include: 0 = Kn of radio-tagged fish was below 95% confidence internal of composite Kn.
1 = Kn of radio-tagged fish was within 95% confidence interval of composite Kn.
2 = Kn of radio-tagged fish was above 95% confidence interval of composite Kn.

[3]I = Primary Incision
1 = poor condition
2 = fair condition
3 = good condition

[4]A = Antenna Exit
1 = poor condition
2 = fair condition
3 = good condition

[5]T = Sum of K, I, and A

Table 24. Summary of information on 15 adult humpback chub processed with a stomach pump and recaptured on a later date, Colorado River, Grand Canyon, 1991-93.

PIT-tag	Date pumped	Last date recaptured	Days at large	Change In Total Length (mm)	Change In Weight (g)	Change In River Mile (mi)
7F7B035620	930319	930325	6	-2	-22	0.15
7F7D180568	920311	930716	492	8	-40	-0.2
7F7D225A0E	930319	930814	148	4	-134	-0.2
7F7D40030C	930320	930516	57	-3	-193	2.35
7F7E430660	920308	920912	188	0	-19	0.85
7F7E432C00	920307	930512	431	-2	-58	-1.15
7F7F050619	930317	930517	61	4	-55	-0.05
7F7F182F27	930318	930323	5	8	-1	-0.15
7F7F1F6B4F	920307	930513	432	0	-107	1.2
7F7F275859	930517	931017	153	-2	44	0
7F7F275859[a]	931017	931210	54	-1	-29	3.85
7F7F295D4F	930516	930917	124	-3	40	1.95
7F7F3E2640	930713	930913	62	2	-39	0
7F7F48032E	930713	931105	115	5	26	0.6
7F7F484445	930317	930915	182	14	-3	0.75

[a]Fish initially pumped in May 1993 recaptured and pumped a second time in October 1993.

Table 25. Comparison of condition factor (Kn) between stomach-pumped recaptured humpback chub and other humpback chub (>200 mm TL) captured during the same sampling trip in the Colorado River in Grand Canyon, 1990-93.

PIT-tag	Kn of Recap.	Adult Population Kn 95% C.I.	No. of adults sampled	Relationship to C.I.	Change in Recap. WT
7F7B035620	1.175	1.057-1.147	58	+	-22
7F7D180568	1.068	0.951-1.003	93	+	-40
7F7D225A0E	0.965	0.892-0.978	39	0	-134
7F7D40030C	1.117	0.914-0.984	92	+	-193
7F7E430660	1.124	1.004-1.090	46	+	-19
7F7E432C00	0.889	0.914-0.984	92	-	-58
7F7F050619	0.795	0.914-0.984	92	-	-55
7F7F182F27	1.282	1.057-1.147	58	+	-1
7F7F1F6B4F	0.856	0.914-0.984	92	-	-107
7F7F275859	0.992	1.006-1.088	44	-	-29
7F7F295D4F	0.999	0.947-1.0074	86	0	+40
7F7F3E2640	0.819	0.947-1.007	86	-	-39
7F7F48032E	0.912	0.953-1.013	39	-	+26
7F7F484445	0.919	0.947-1.007	86	-	-3

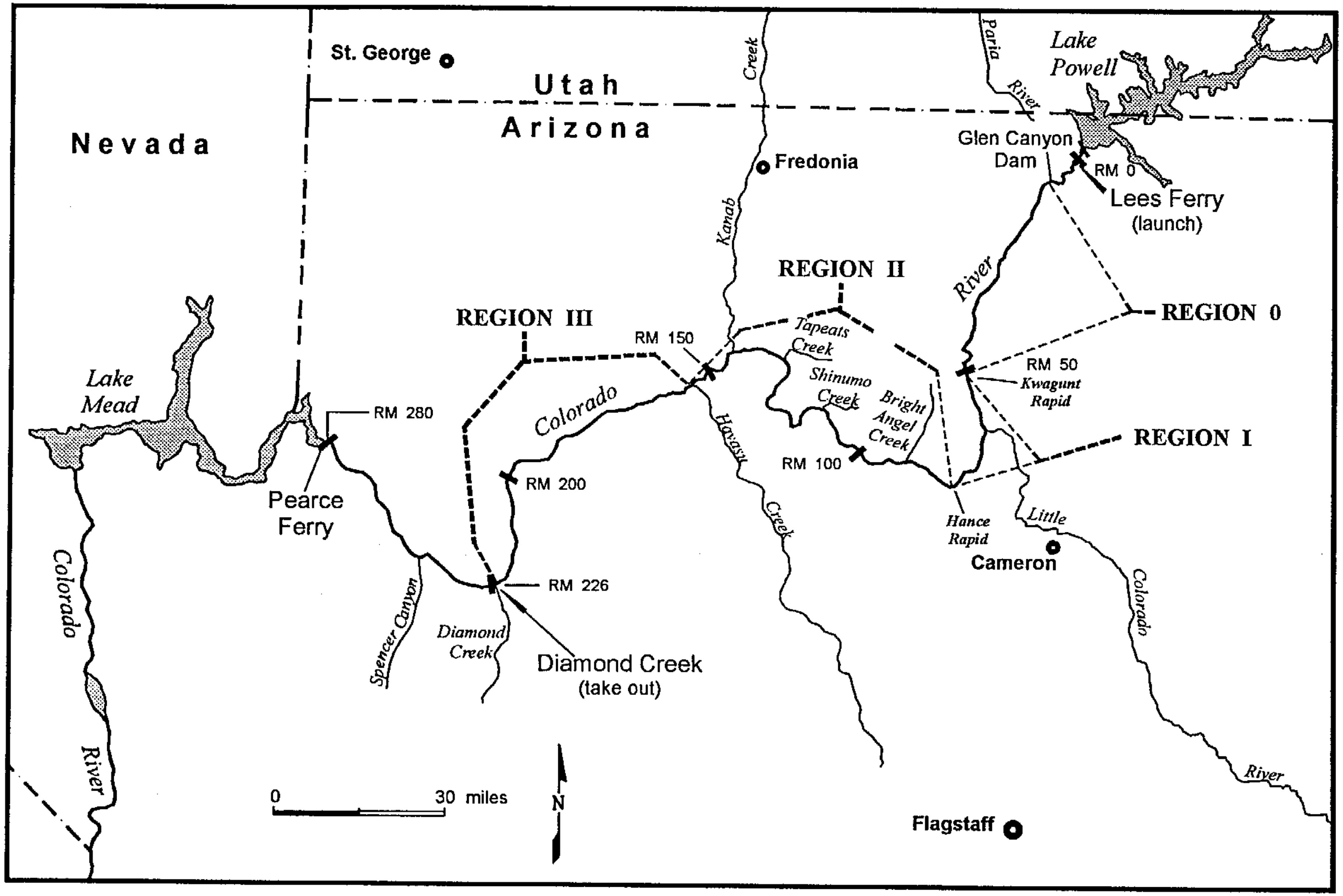


Fig. 1. BIO/WEST study area in Grand Canyon and four sample regions.

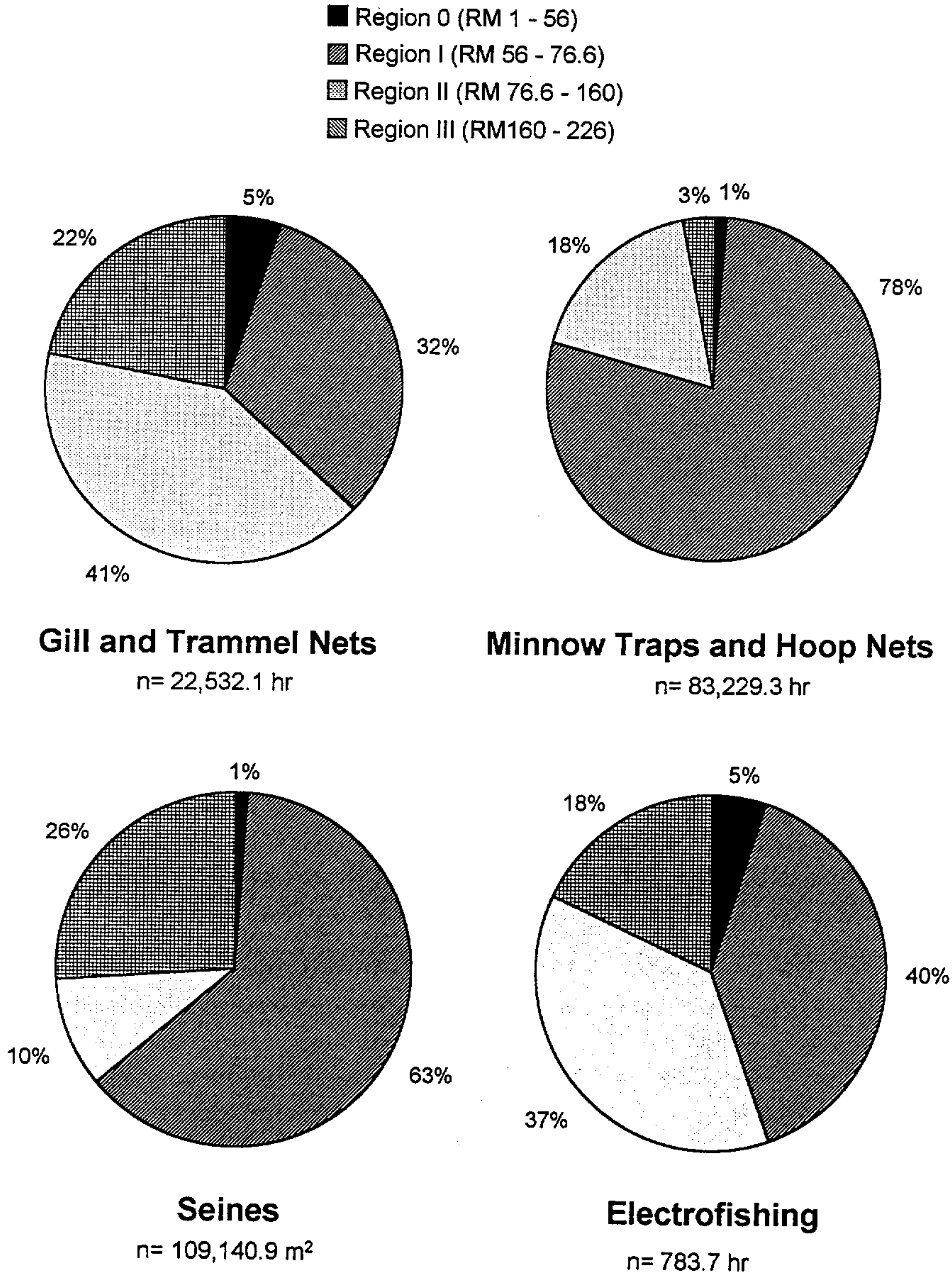


Fig. 2. Relative effort for fish sampling gears by study region. Numbers are percentage of total hours (n) for nets, traps, and electrofishing; and percentage of total area in square meters (n) for seines.

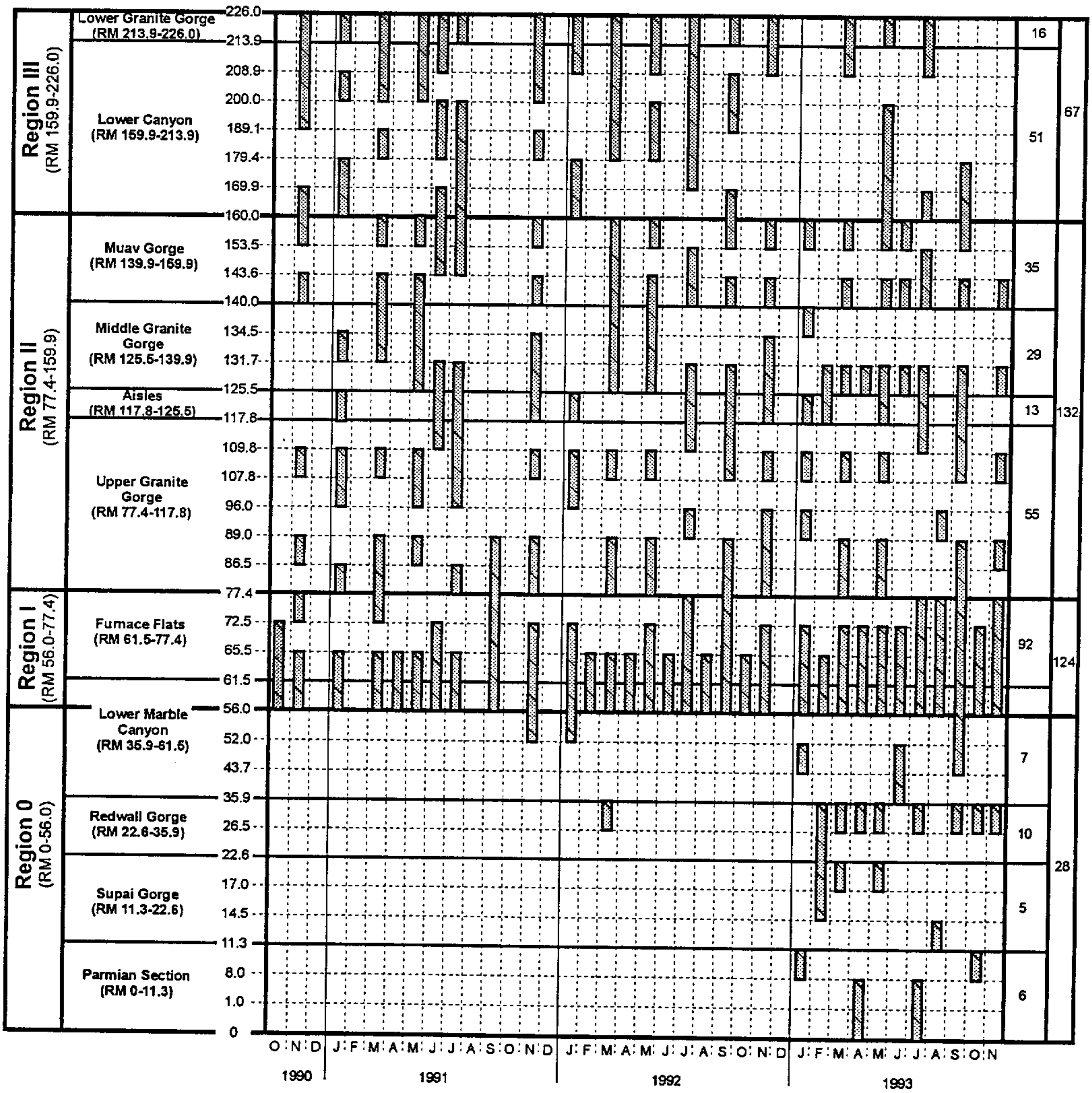


Fig. 3. Monthly sample efforts on the Colorado River by geomorphic reach and study region (numbers at right show occurrence) from Lees Ferry to Diamond Creek.

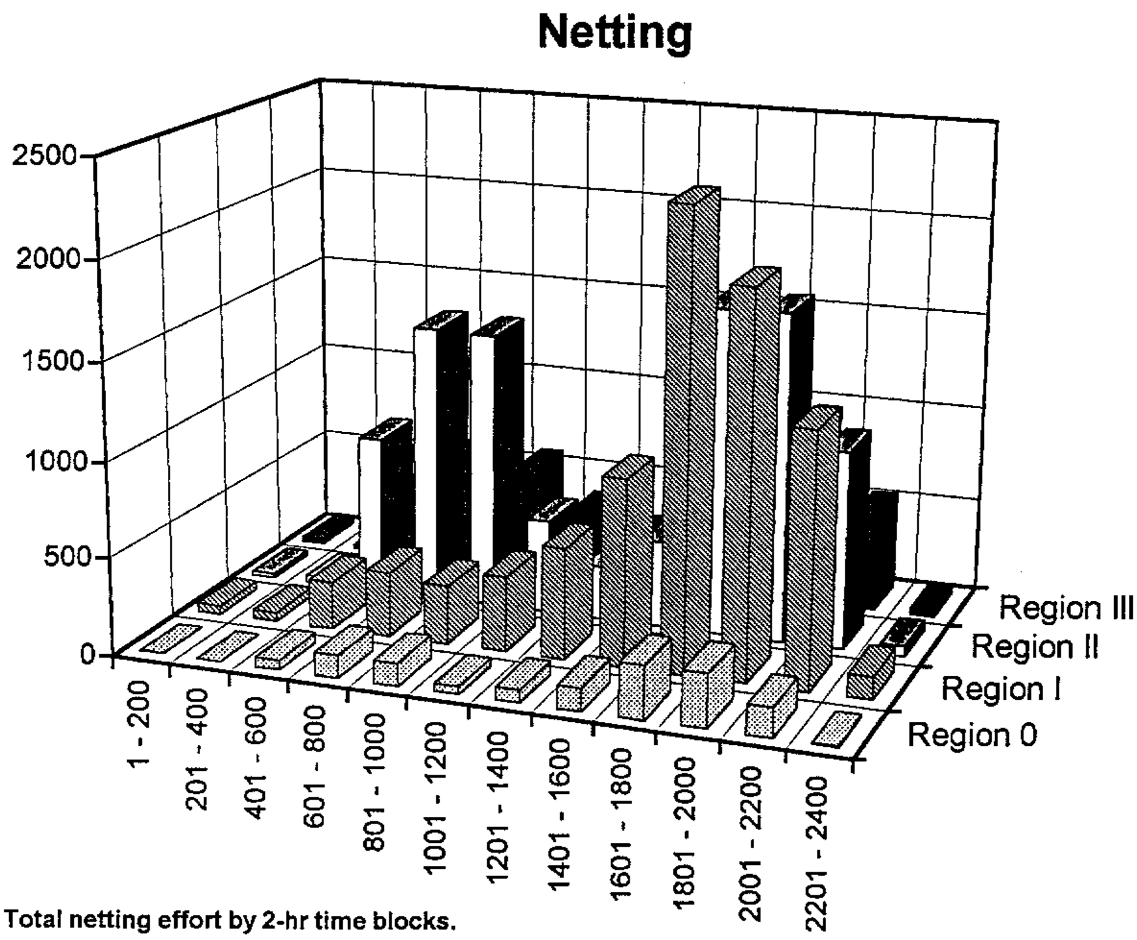


Fig. 4. Total netting effort by 2-hr time blocks.

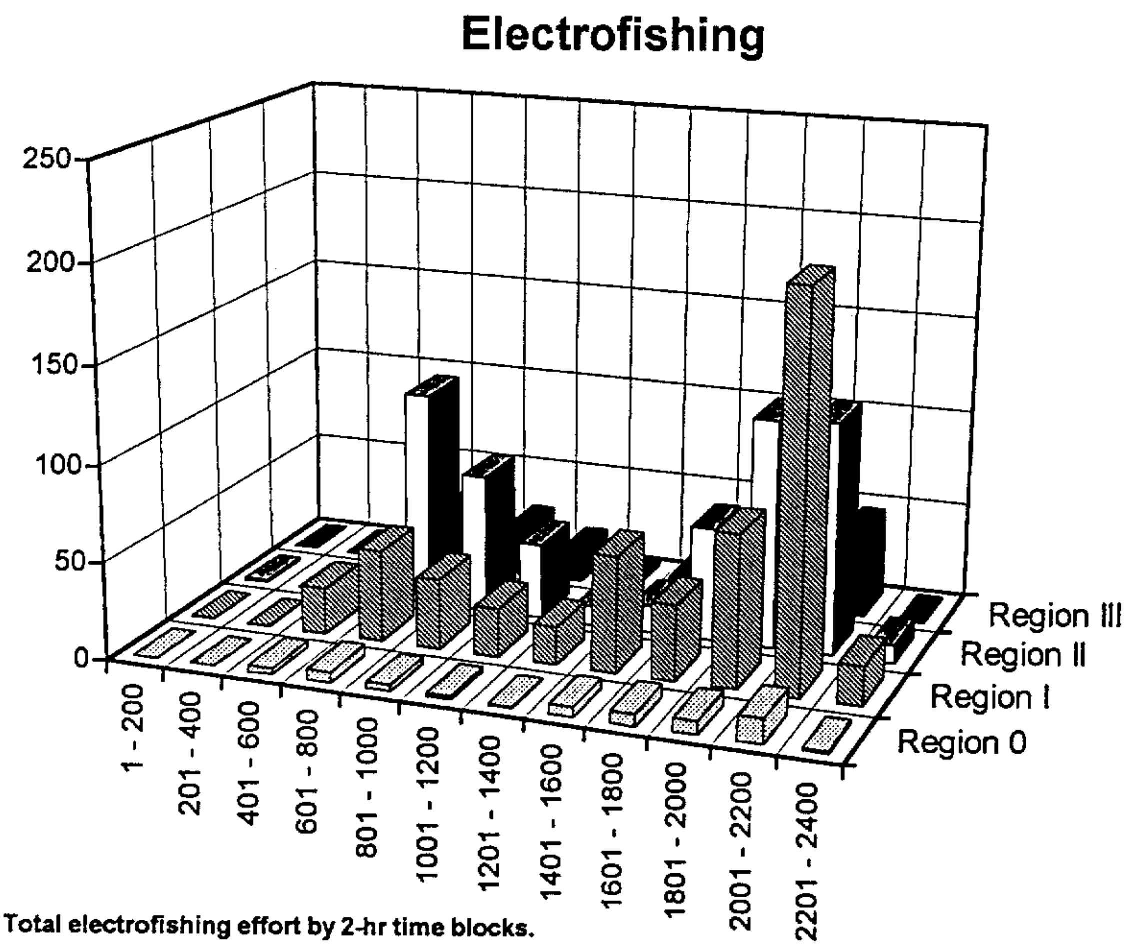
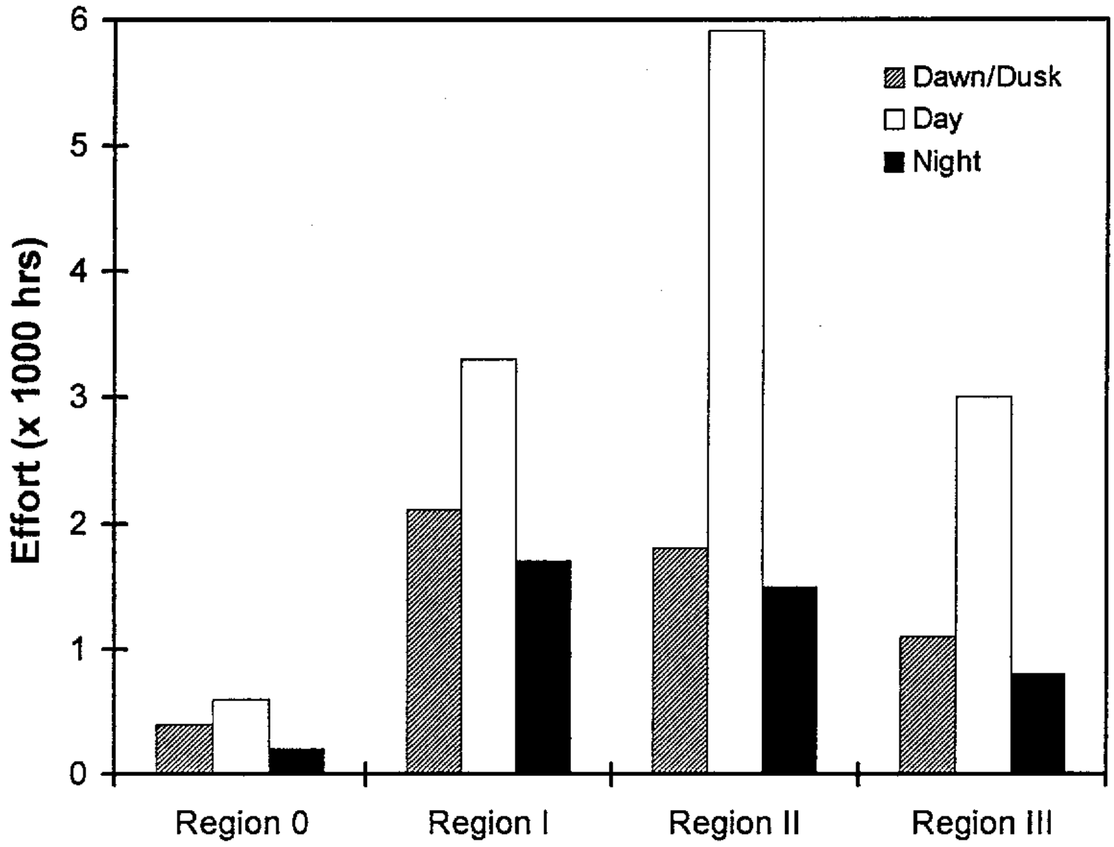


Fig. 5. Total electrofishing effort by 2-hr time blocks.



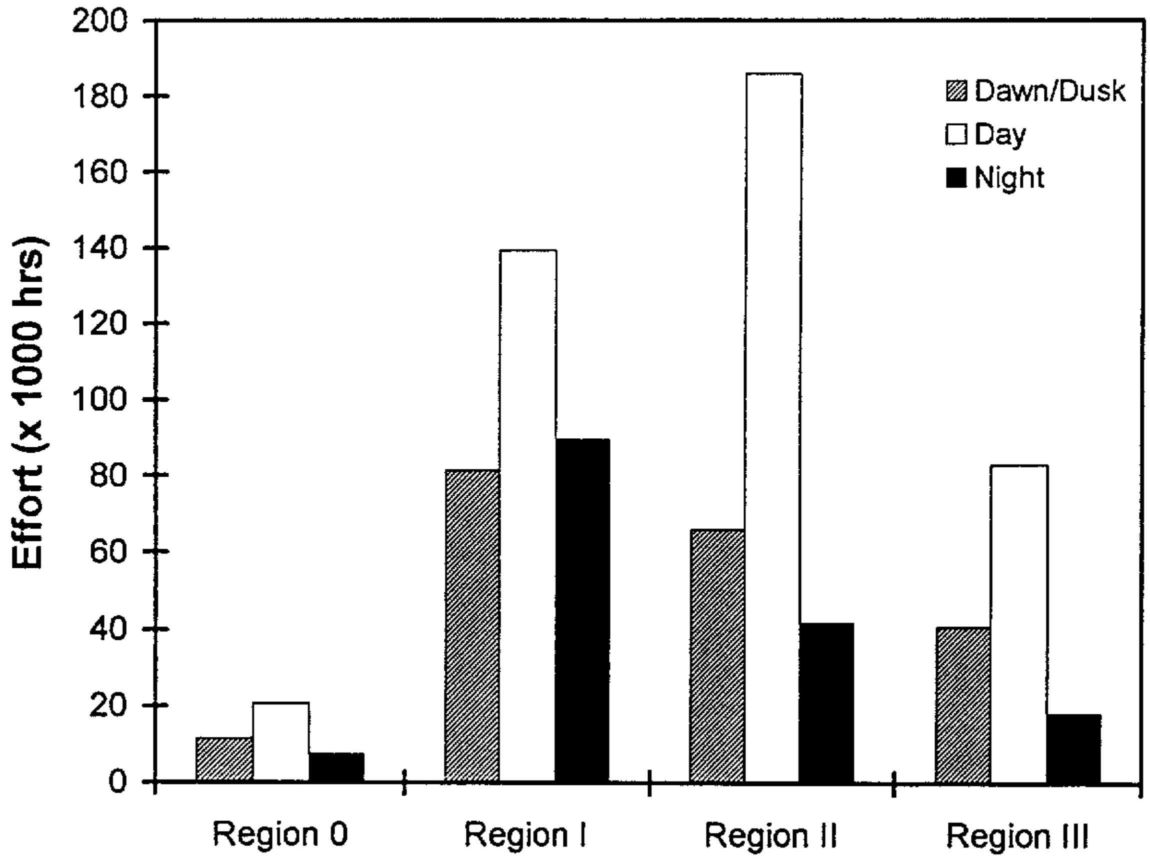


Fig. 6. Total netting and electrofishing effort during dawn/dusk, day and night within four study regions.

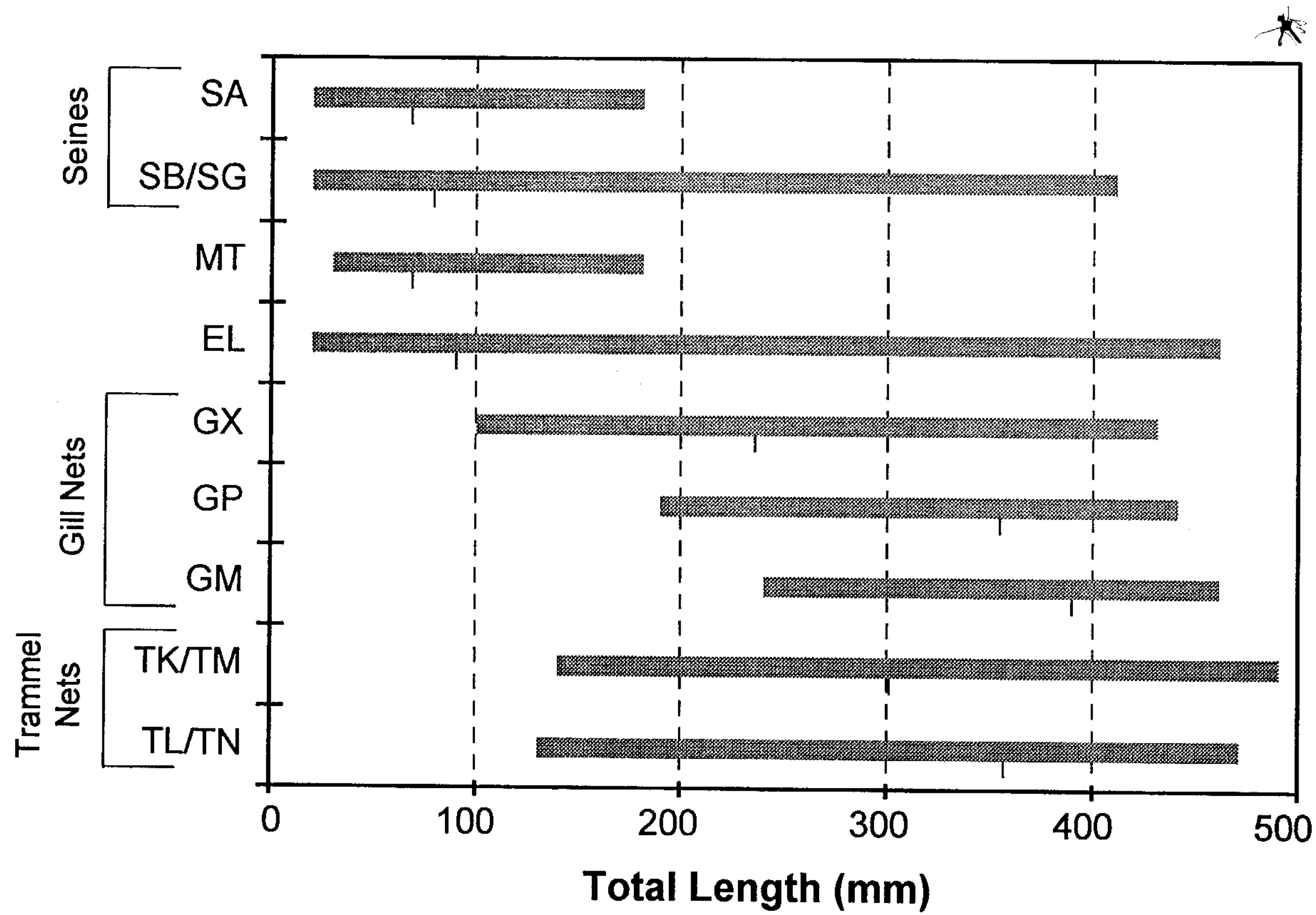


Fig. 7. Minimum, maximum, and mean length of humpback chub captured with nine gear types. See table 4 for explanation of gear codes.

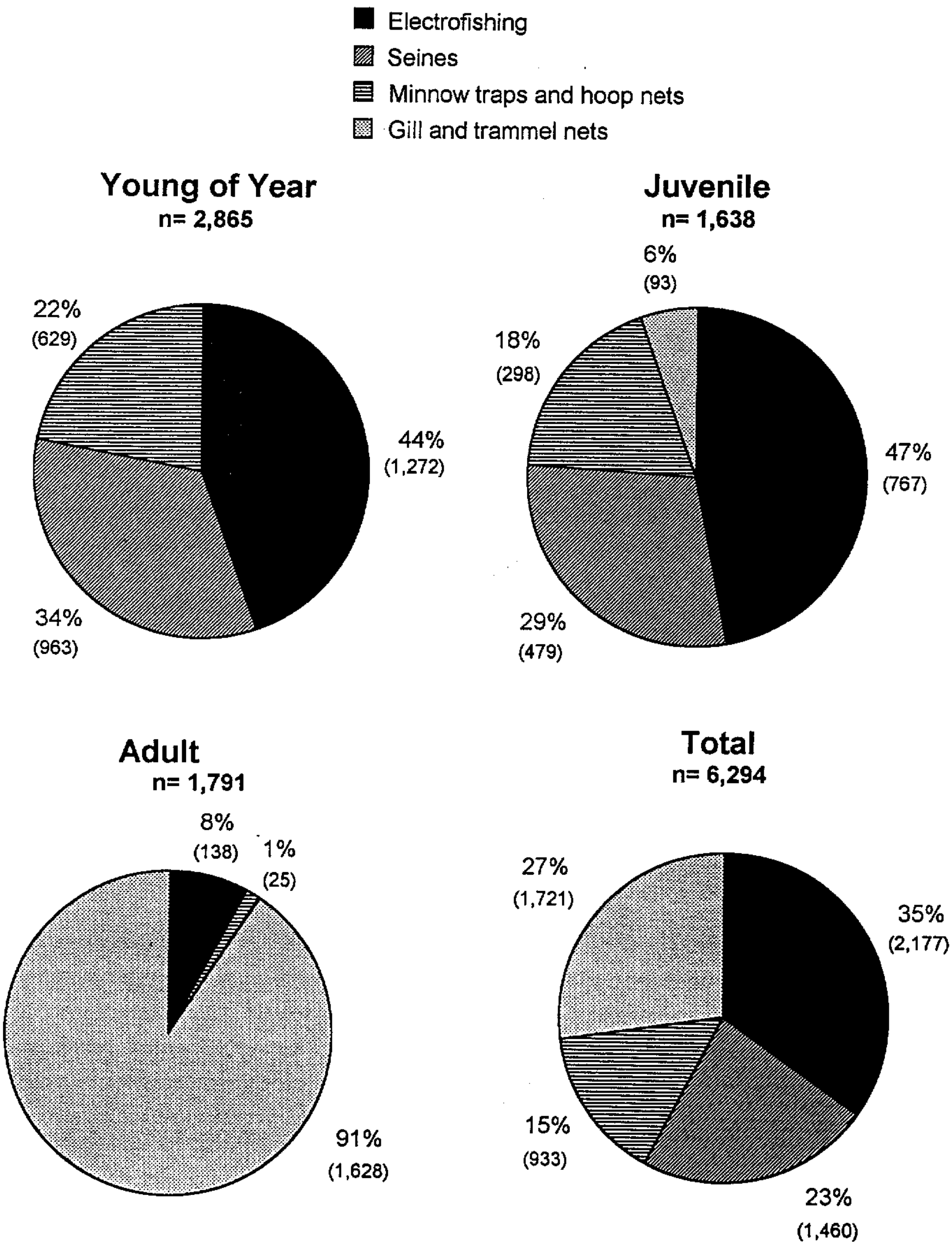


Fig. 8. Percentage (number) of humpback chub captured by age category with fish sampling gears.

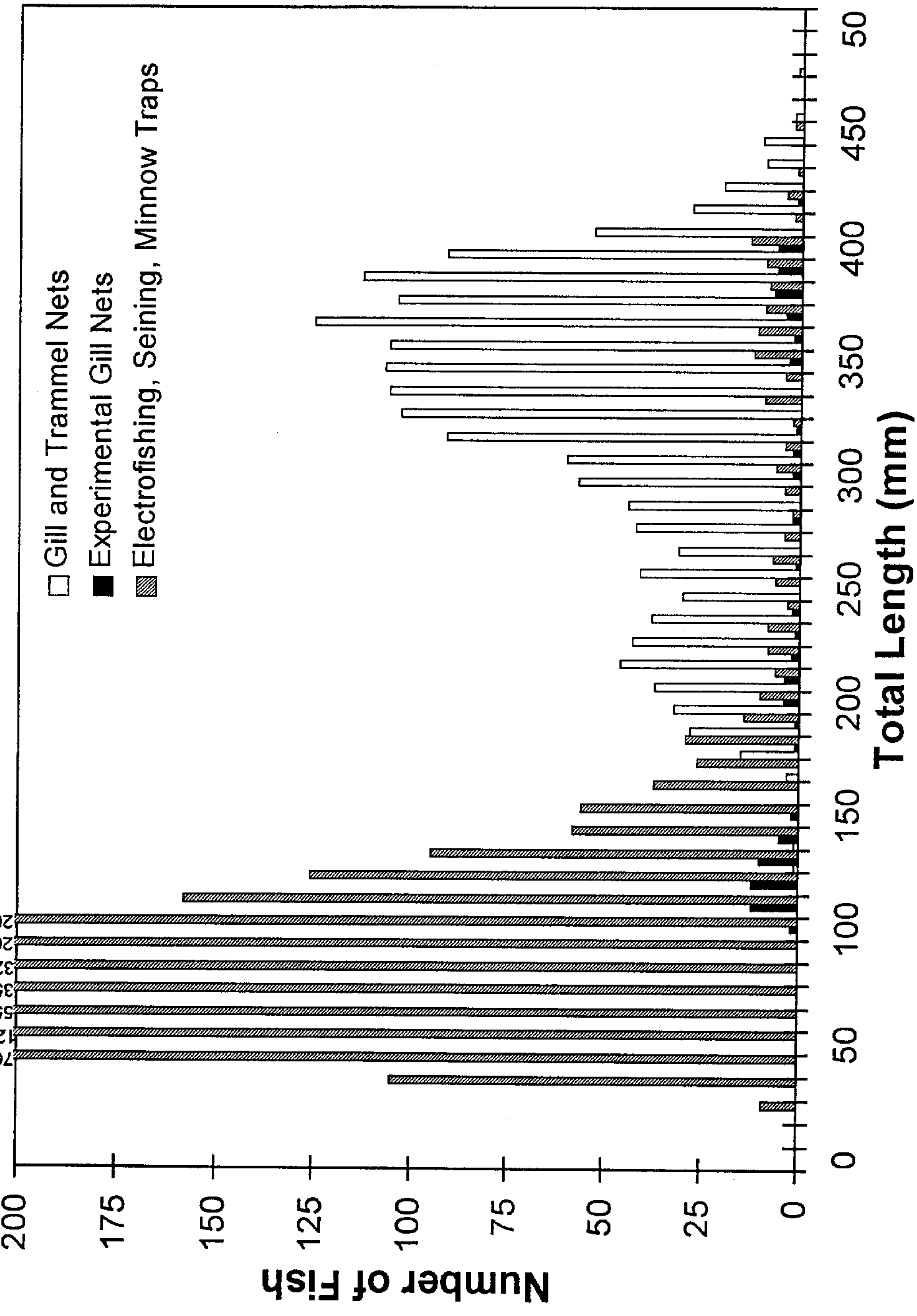


Fig. 9. Pooled length-frequency histogram for humpback chub captured with three gear type groups.

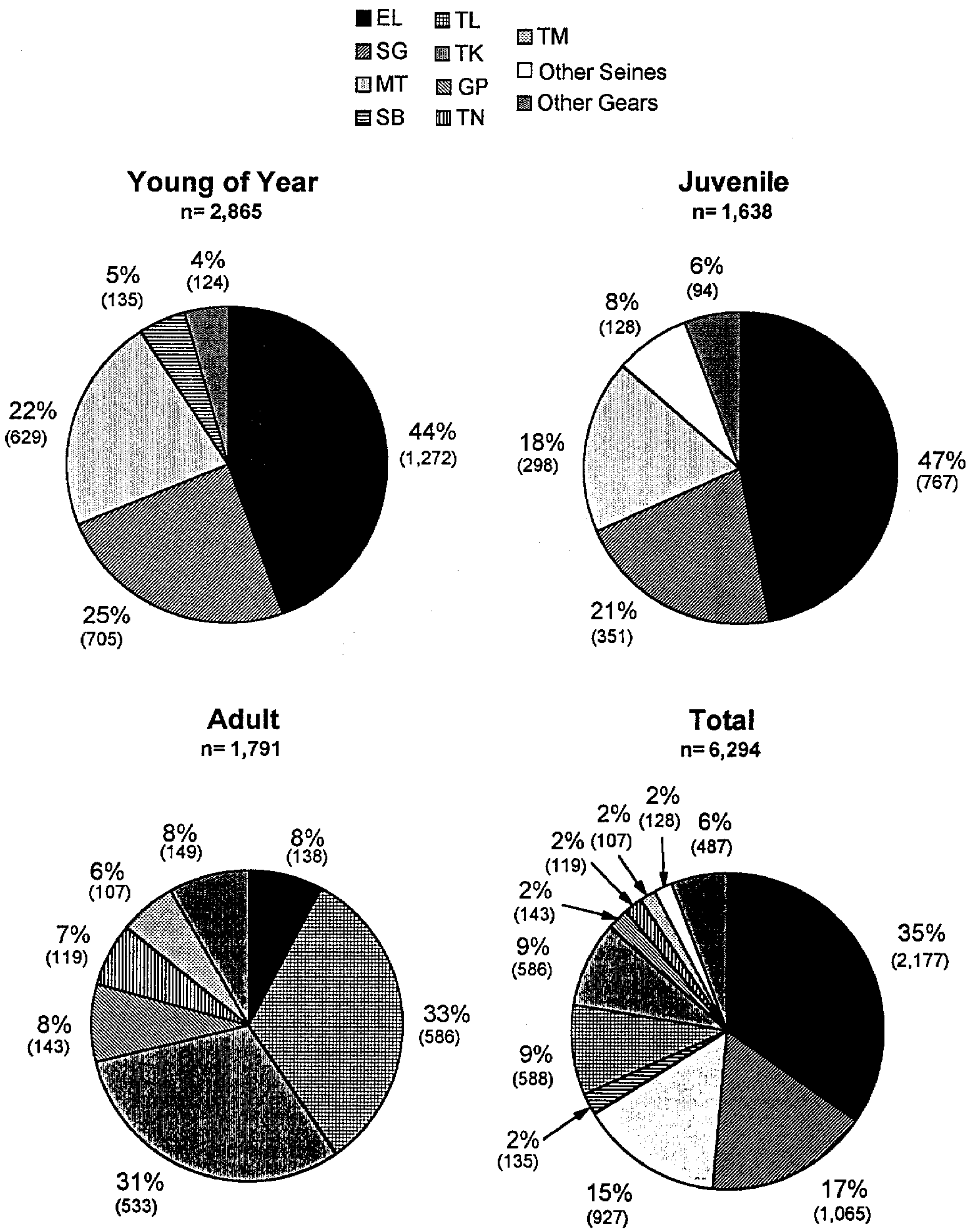


Fig. 10. Percentage (number) of humpback chub captured by age category with primary gear types. See Table 4 for code definitions. n= total number of individuals.

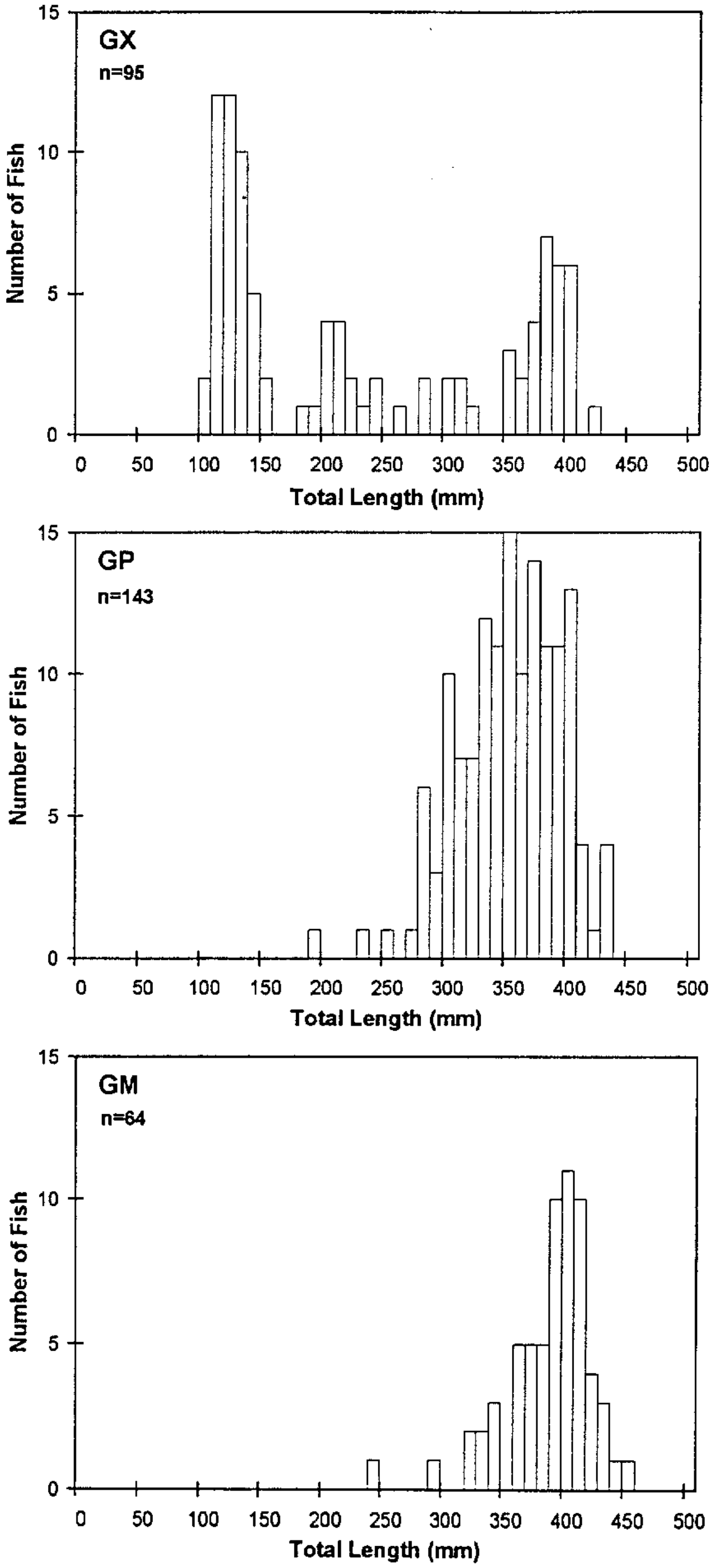


Fig. 11. Pooled length-frequency histogram for humpback chub captured with gill nets (GX, GP, GM). See Table 4 for code descriptions.

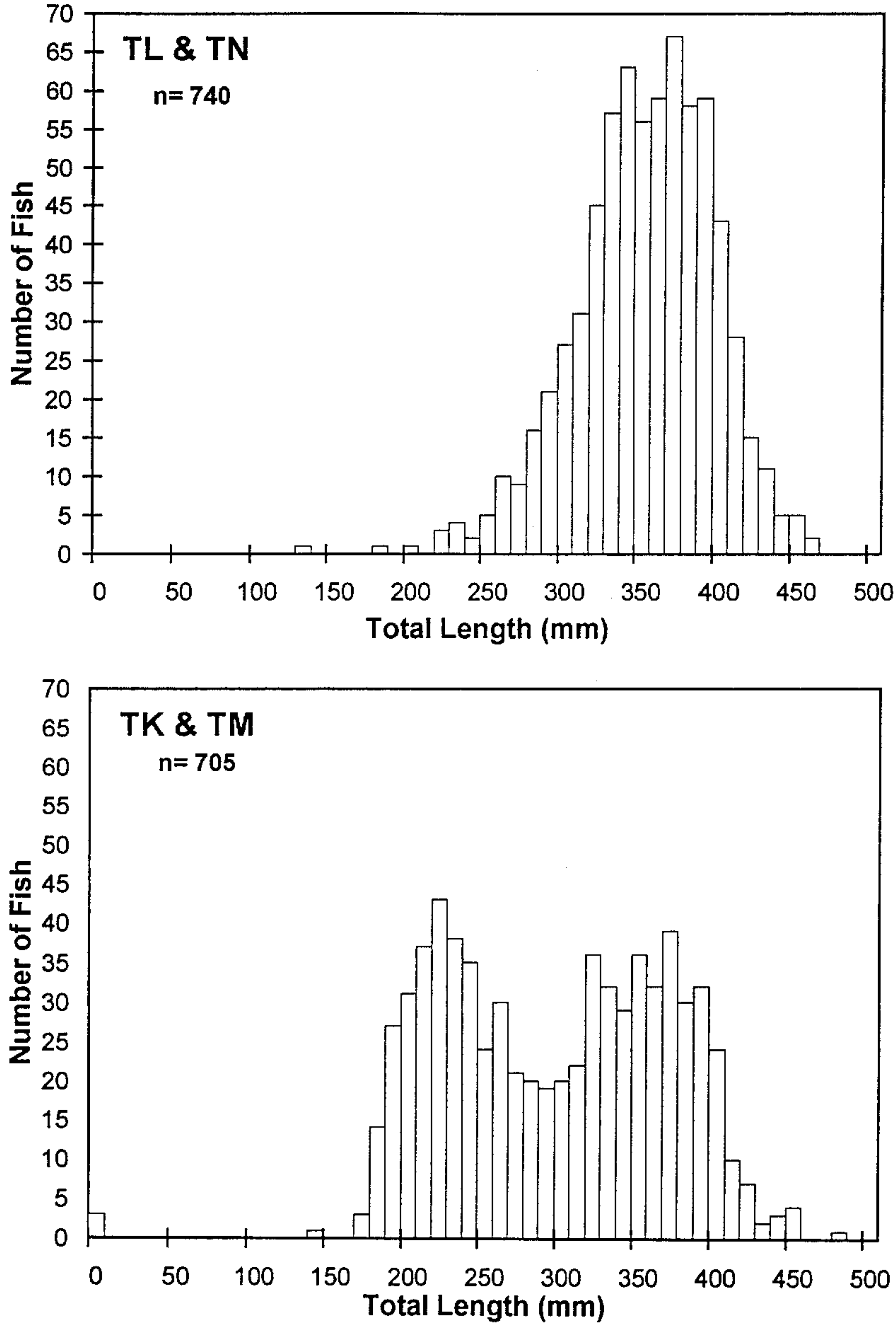


Fig. 12. Pooled length-frequency histograms for humpback chub captured with trammel nets (TL, TN, TK, TM). See Table 4 for code descriptions.

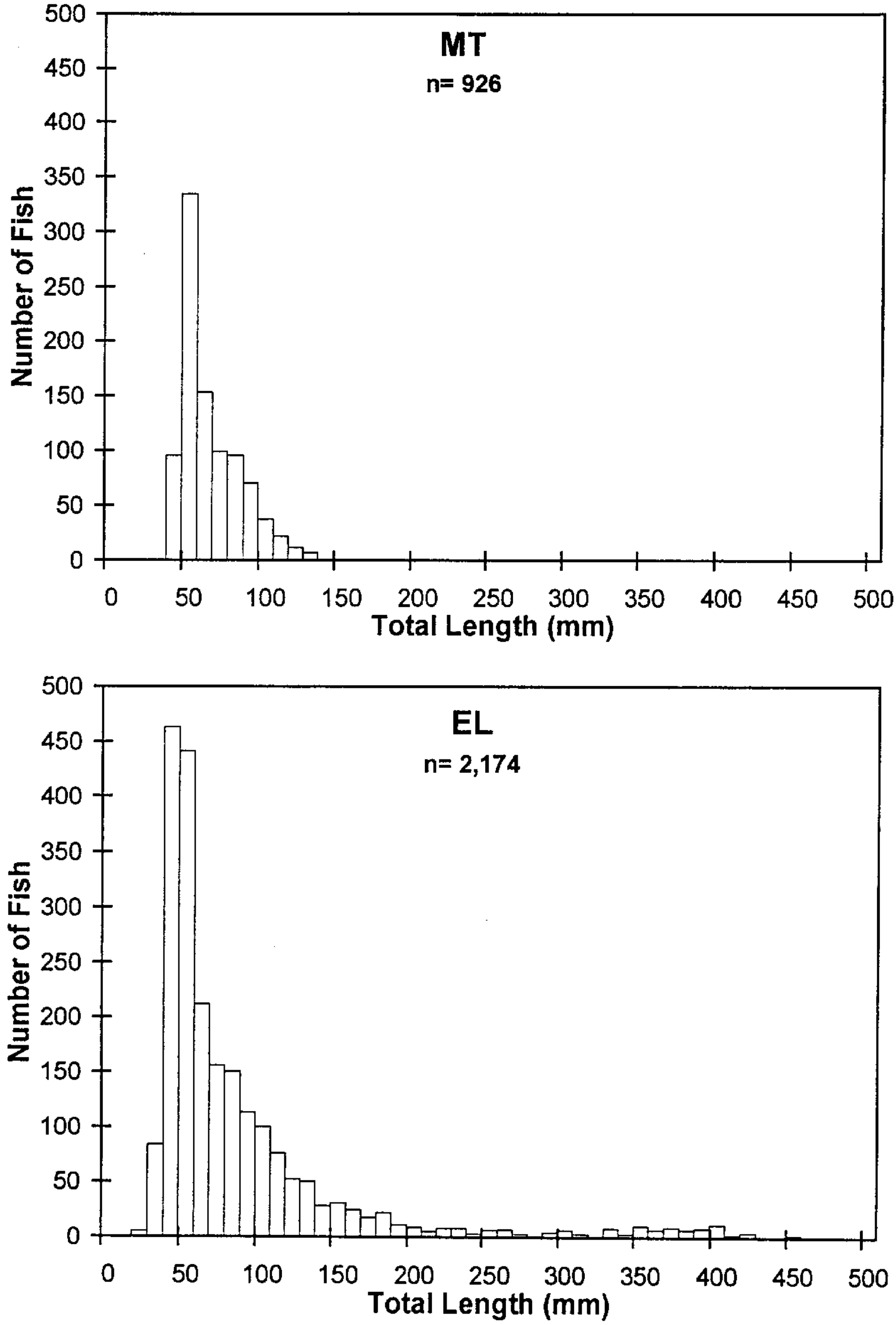


Fig. 13. Pooled length-frequency histograms for humpback chub captured with minnow traps (MT) and electrofishing (EL). See Table 4 for code descriptions.

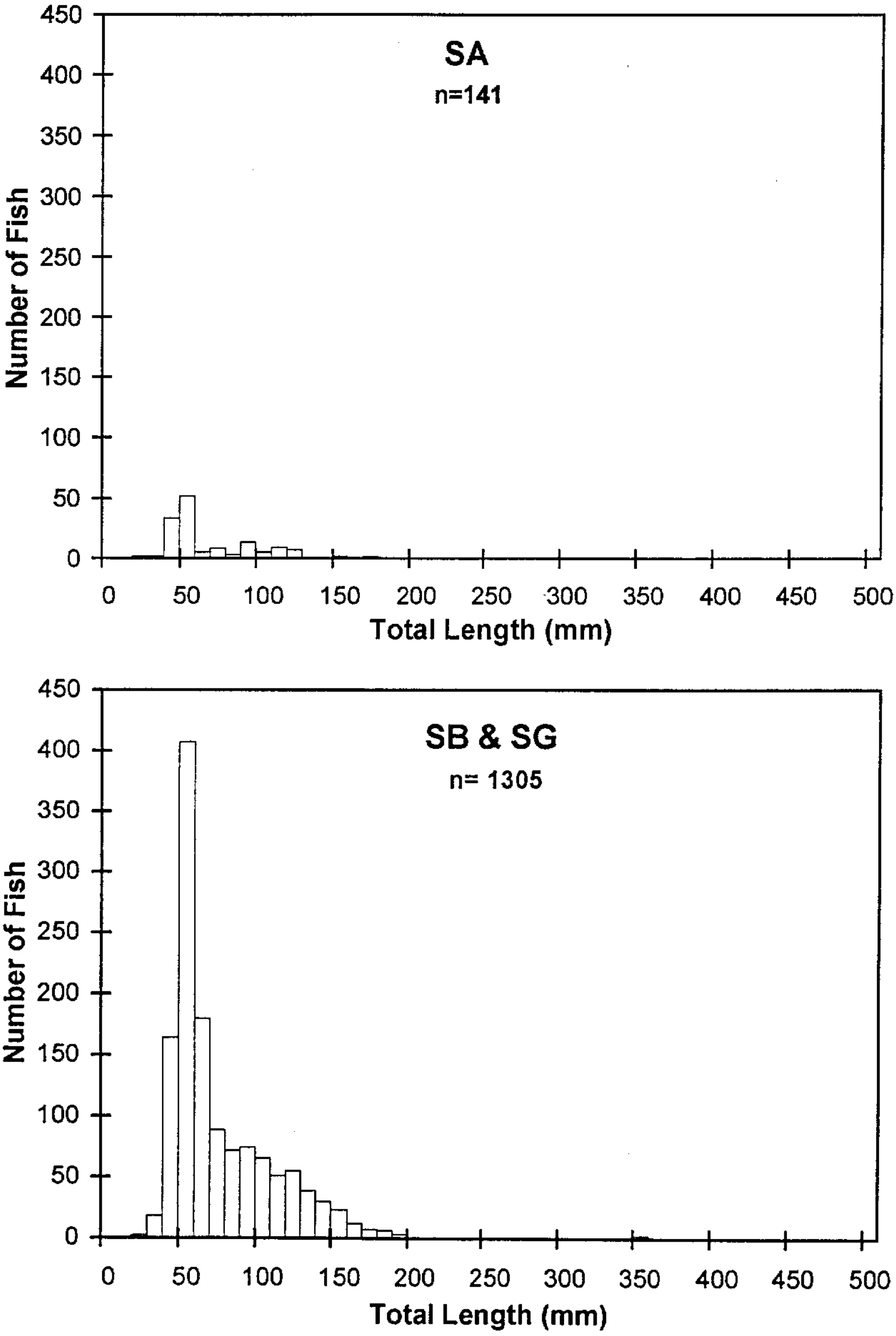


Fig. 14. Pooled length-frequency histograms for humpback chub captured with seines (SA, SB, SG). See Table 4 for code descriptions.

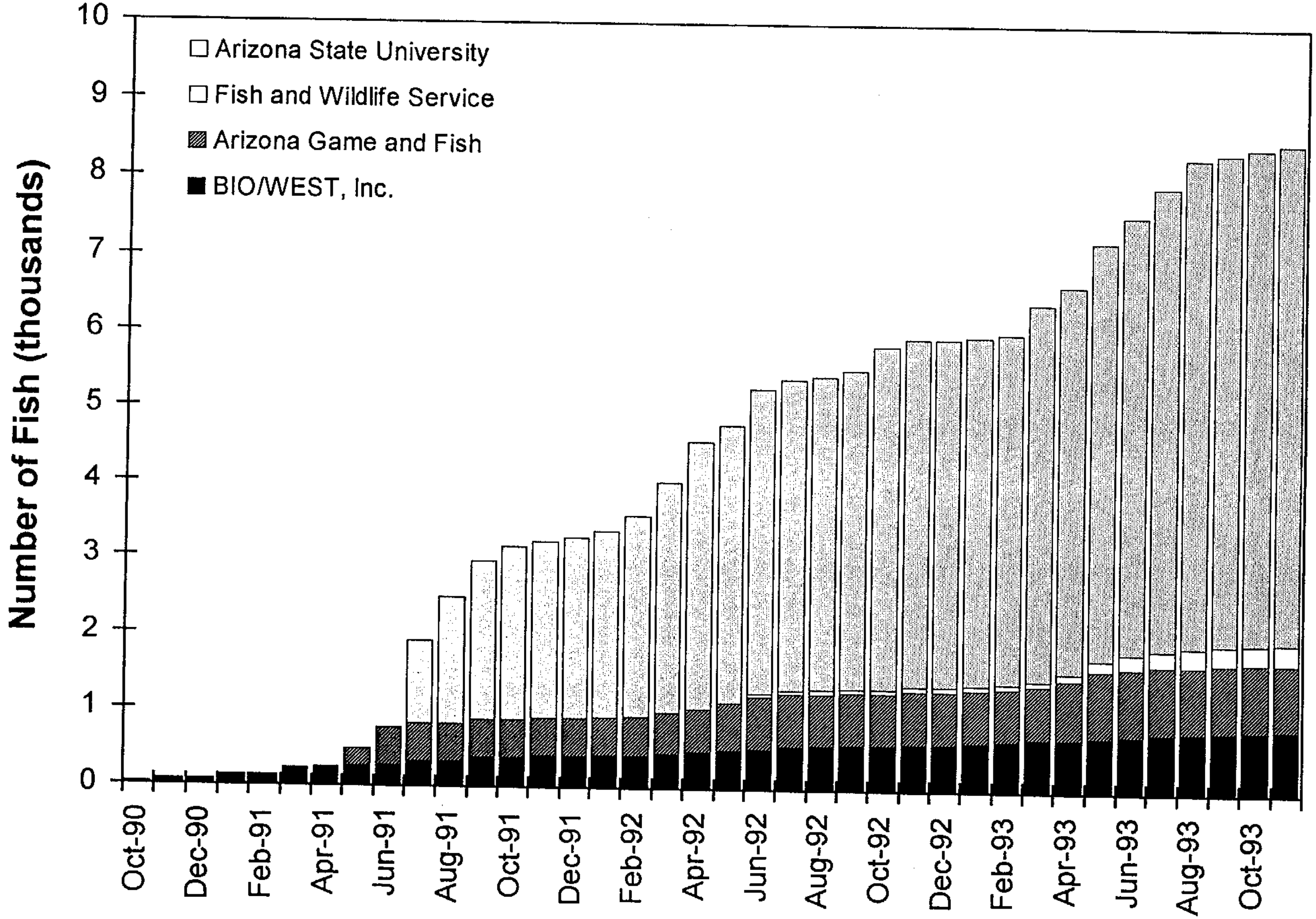


Fig. 15. Cumulative number of humpback chub PIT-tagged by all investigators in Grand Canyon, October 1990 - November 1993.

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Table 5. Total sample effort and arithmetic mean catch rate (AMcpe) of adult, juvenile and YOY humpback chub by gear in the four study regions.

GEAR[a]	Total samples (Total time - hr)				AMcpe (number of fish)											
	REGION				Adult HB REACH				Juvenile HB REGION				YOY HB REGION			
	0	I	II	III	0	I	II	III	0	I	II	III	0	I	II	III
GILL AND TRAMMEL NETS[b]																
GM	63 (134.4)	378 (791.8)	298 (604.8)	193 (414.1)	0	8.1 (64)	0.12 (1)	0	0	0	0	0	0	0	0	0
GP	56 (119.4)	477 (1006.0)	507 (1030.1)	281 (595.7)	1.17 (1)	14.4 (139)	0.3 (3)	0	0	0.1 (1)	0	0	0	0	0	0
GX	0	180 (374.1)	174 (368.0)	155 (318.5)	-	15.7 (47)	1.6 (4)	0	-	11.1 (44)	0.4 (1)	0	-	0	0	0
GZ	0	0	16 (31.4)	14 (27.2)	-	-	0	0	-	-	0	0	-	-	0	0
TK	174 (371.7)	989 (2060.0)	1263 (2634.9)	803 (1667.0)	1.91 (6)	32.2 (468)	3.4 (75)	0.25 (3)	0	1.8 (26)	0.4 (8)	0	0	0	0	0
TL	137 (295.6)	1044 (2165.1)	1386 (2876.3)	668 (1436.7)	4.2 (8)	32.6 (533)	6.6 (39)	0.5 (6)	0	0.1 (2)	0	0	0	0	0	0
TM	49 (110.7)	189 (393.0)	390 (803.3)	119 (243.3)	9.2 (5)	35.5 (63)	10.0 (37)	1.6 (2)	0	5.5 (9)	0.7 (3)	0	0	0	0	0
TN	43 (92.8)	175 (362.9)	410 (858.6)	139 (285.1)	7.8 (4)	55.3 (103)	2.9 (12)	0	0	0	0	0	0	0	0	0
TW	8 (15.7)	3 (6.1)	11 (21.5)	0	0	0	0	-	0	0	0	-	0	0	0	-
TY	0	6 (11.1)	0	0	-	43.8 (3)	-	-	-	0	-	-	-	0	-	-
TZ	0	3 (5.2)	0	0	-	24.4 (1)	-	-	-	0	-	-	-	0	-	-
Total	**530 (1140.3)**	**3444 (7175.3)**	**4455 (9228.9)**	**2372 (4987.6)**												
MINNOW TRAPS AND HOOP NETS[c]																
HL	0	4 (37.1)	40 (687.5)	19 (316.1)	-	5.6 (2)	0	0	-	0	0.1 (1)	0	-	0	0.1 (1)	0
HM	0	2 (38.8)	13 (191.3)	2 (39.3)	-	0	0	0	-	0	0	0	-	0	0	0
HS	0	4 (30.8)	73 (1187.6)	9 (150.4)	-	2.0 (1)	0.63 (1)	0	-	0	0	0	-	0	0	0
MT	12 (210.3)	3847 (65866.7)	622 (12752.2)	81 (1721.2)	0	0	0	0	0	0.5 (271)	0.2 2 (10)	0	0	1.14 (638)	0.13 (9)	0

Total	**12 (210.3)**	**3857 (65973.4)**	**748 (14818.6)**	**111 (2227.0)**												
					SEINES[d]											
		(area m²)														
SA	0	42 (7000.0)	54 (5983.4)	17 (2689.0)	-	0	0	0	-	4.3 (45)	0.3 (6)	0	-	6.8 (72)	1.6 (18)	0
SB	13 (779.0)	48 (6605.5)	19 (2901.0)	3 (276.0)	0	0.1 (2)	0	0	0	1.2 (42)	0	0	0	2.7 (135)	0	0
GF	0	6 (1350.0)	0	0	-	0.1 (2)	-	-	-	0	-	-	-	0	-	-
SG	1 (60.0)	297 (53748.0)	15 (1789.0)	15 (3460.0)	0	0.03 (9)	0	0	0	2.1 (346)	0.1 (3)	0.1 (2)	0	4.1 (704)	0.03 (1)	0
TF	0	0	0	2 (22500.0)	-	-	-	0	-	-	-	0	-	-	-	0
Qual	5	46	21	11	-	-	-	-	-	-	-	-	-	-	-	-
Total	**19 (839.0)**	**439 (68703.5)**	**109 (10673.4)**	**50 (28925.0)**												
					ELECTROFISHING[e]											
EL	217 (40.8)	1319 (308.5)	909 (293.4)	441 (141.0)	0.43 (2)	5.8 (125)	0.5 (9)	0.1 (1)	0	24.9 (742)	0.4 (11)	0	0	55.1 (1283)	0.1 (3)	0
					ANGLING[f]											
AL	-	-	-	-	-	- (2)	-	-	-	-	-	-	-	-	-	-
AN	-	-	-	-	-	- (1)	-	-	-	-	-	-	-	-	-	-

[a]See Table 5-1 for gear codes.
[b]CPE = fish/100 ft/100 hr
[c]CPE = fish/100 hr
[d]CPE = fish/100 m²
[e]CPE = fish/10 hr
[f]no effort recorded

Table 6. Arithmetic mean catch rate (AMcpe) of adult, juvenile and YOY flannelmouth sucker by gear in the Colorado River in Grand Canyon, October 1990-November 1993.

GEAR[a]	Total samples (Total time - hr)				AMcpe (number of fish)											
					Adult FM				Juvenile FM				YOY FM			
	REGION				REGION				REGION				REGION			
	0	I	II	III	0	I	II	III	0	I	II	III	0	I	II	III
NETS[b]																
GM	63 (134.4)	378 (791.8)	298 (604.8)	193 (414.1)	0.7 (1)	14.2 (113)	2.9 (18)	0	0	0	0	0	0	0	0	0
GP	56 (119.4)	477 (1006.0)	507 (1030.1)	281 (595.7)	0	5.7 (60)	2.1 (23)	1.5 (8)	0	0	0	0	0	0	0	0
GX	0	180 (374.1)	174 (368.0)	155 (318.5)	-	14.7 (49)	0.3 (1)	2.6 (9)	-	0.3 (1)	0	0.3 (1)	-	0	0	0
GZ	0	0	16 (31.4)	14 (27.2)	-	-	0	0	-	-	0	0	-	-	0	0
TK	174 (371.7)	989 (2060.0)	1263 (2634.9)	803 (1667.0)	1.6 (4)	14.1 (206)	8.5 (173)	5.2 (65)	0	0	0.1 (1)	0	0	0	0	0
TL	137 (295.6)	1044 (2165.1)	1386 (2876.3)	668 (1436.7)	4.8 (8)	22.5 (378)	10.5 (223)	3.1 (32)	0	0	0	0	0	0	0	0
TM	49 (110.7)	189 (393.0)	390 (803.3)	119 (243.3)	8.8 (5)	10.1 (21)	14.2 (61)	30.5 (38)	0	0	0	0	0	0	0	0
TN	43 (92.8)	175 (362.9)	410 (858.6)	139 (285.1)	4.1 (2)	36.5 (69)	16.4 (72)	30.2 (47)	0	0	0	0	0	0	0	0
TW	8 (15.7)	3 (6.1)	11 (21.5)	0	0	0	0	-	-	-	0	0	-	-	0	0
TY	0	6 (11.1)	0	0	-	27.4 (2)	-	-	-	0	-	-	-	0	-	-
TZ	0	3 (5.2)	0	0	-	20.2 (1)	-	-	-	0	-	-	-	0	-	-
Totals	530 (1140.3)	3444 (7175.3)	4455 (9228.9)	2372 (4987.6)												
TRAPS[c]																
HL	0	4 (37.1)	40 (687.5)	19 (316.1)	-	0	19.1 (162)	17.6 (48)	-	0	1.9 (16)	0.7 (3)	-	0	0	0
HM	0	2 (38.8)	13 (191.3)	2 (39.3)	-	0	0	0	-	0	0	0	-	0	0	0
HS	0	4 (30.8)	73 (1187.6)	9 (150.4)	-	0	0.8 (10)	6.6 (10)	-	0	2.1 (30)	2.8 (4)	-	0	0	0
MT	12 (210.3)	3847 (65866.7)	622 (12752.2)	81 (1721.2)	0	0	0	0	0	0.01 (5)	0.2 (16)	0.1 (1)	0	0	0	0

Totals	**12 (210.3)**	**3857 (65973.4)**	**748 (14818.6)**	**111 (2227.0)**												
								SEINES[e]								
		(area m²)														
SA	0	42 (7000.0)	54 (5983.4)	17 (2689.0)	-	0	0.2 (9)	0	0	0.6 (7)	0.3 (12)	0.7 (5)	-	0.4 (5)	0	1.3 (3)
SB	13 (779.0)	48 (6605.5)	19 (2901.0)	3 (276.0)	0	0	0	0	0	0.1 (6)	0.02 (1)	0	0	0.1 (6)	0	0
GF	0	6 (1350.0)	0	0	-	0.3 (4)	-	-	-	0	-	-	-	0	-	-
SG	1 (60.0)	297 (53748.0)	15 (1789.0)	15 (3460.0)	0	0.02 (7)	0	0.1 (1)	0	0.2 (86)	0.1 (1)	0.9 (31)	0	0.5 (85)	0	2.2 (13)
TF	0	0	0	2 (22500.0)	-	-	-	0	-	-	-	0	-	-	-	0
Qual	5	46	21	11	-	-	-	-	-	-	-	-	-	-	-	-
Total	**19 (839.0)**	**439 (68703.5)**	**109 (10673.4)**	**50 (28925.0)**												
								ELECTROFISHING[d]								
EL	217 (40.8)	1319 (308.5)	909 (293.4)	441 (141.0)	42.1 (44)	3.6 (80)	3.4 (72)	5.0 (50)	0	1.4 (42)	2.2 (52)	3.7 (46)	0	0.7 (19)	0.02 (1)	0.2 (1)

[a]See Table 4-1 for gear codes.
[b]CPE = fish/100 ft/100 hr
[c]CPE = fish/100 hr
[d]CPE = fish/10 hr
[e]CPE = fish/100 m²
[f]CPE = fish/10 hr

Table 7. Arithmetic mean catch rate (AMcpe) of adult, juvenile and YOY bluehead sucker by gear in the Colorado River in Grand Canyon, October 1990-November 1993.

GEAR[a]	Total samples (Total time - hr) REGION 0	I	II	III	AMcpe (number of fish) Adult BH REGION 0	I	II	III	Juvenile BH REGION 0	I	II	III	YOY BH REGION 0	I	II	III
NETS[b]																
GM	63 (134.4)	378 (791.8)	298 (604.8)	193 (414.1)	0	0	0.2 (1)	0	0	0	0	0	0	0	0	0
GP	56 (119.4)	477 (1006.0)	507 (1030.1)	281 (595.7)	0	0.6 (6)	0.3 (3)	0.5 (3)	0	0	0	0	0	0	0	0
GX	0	180 (374.1)	174 (368.0)	155 (318.5)	-	2.7 (7)	0.2 (1)	0.7 (2)	-	0	0	0	-	0	0	0
GZ	0	0	16 (31.4)	14 (27.2)	-	0	0	-	-	0	0	-	-	0	0	-
TK	174 (371.7)	989 (2060.0)	1263 (2634.9)	803 (1667.0)	0.3 (1)	5.2 (76)	3.1 (60)	2.0 (24)	0	0	0	0	0	0	0	0
TL	137 (295.6)	1044 (2165.1)	1386 (2876.3)	668 (1436.7)	0.6 (1)	1.1 (18)	1.1 (24)	0.9 (9)	0	0	0	0	0	0	0	0
TM	49 (110.7)	189 (393.0)	390 (803.3)	119 (243.3)	0	8.8 (17)	3.5 (14)	0.8 (1)	0	0	0	0	0	0	0	0
TN	43 (92.8)	175 (362.9)	410 (858.6)	139 (285.1)	0	3.5 (6)	0.8 (4)	8.6 (13)	0	0	0	0	0	0	0	0
TW	8 (15.7)	3 (6.1)	11 (21.5)	0	0	0	0	-	0	0	0	-	0	0	0	-
TY	0	6 (11.1)	0	0	-	0	-	-	-	0	-	-	-	0	-	-
TZ	0	3 (5.2)	0	0	-	0	-	-	-	0	-	-	-	0	-	-
Totals	**530 (1140.3)**	**3444 (7175.3)**	**4455 (9228.9)**	**2372 (4987.6)**												
TRAPS[c]																
HL	0	4 (37.1)	40 (687.5)	19 (316.1)	-	7.0 (2)	4.8 (35)	18.9 (71)	-	0	0.4 (3)	0.9 (3)	-	0	0	0
HM	0	2 (38.8)	13 (191.3)	2 (39.3)	-	0	0	0	-	0	0	0	-	0	0	0
HS	0	4 (30.8)	73 (1187.6)	9 (150.4)	-	2.0 (1)	5.6 (73)	83.4 (148)	-	0	0.9 (13)	7.5 (14)	-	0	0	0
MT	12 (210.3)	3847 (65866.7)	622 (12752.2)	81 (1721.2)	0	0	0	0	0	0.001 (1)	0.1 (8)	0	0	0.001 (1)	0	0

Totals	**12 (210.3)**	**3857 (65973.4)**	**748 (14818.6)**	**111 (2227.0)**												
								SEINES[e]								
		(area m²)														
SA	0	42 (7000.0)	54 (5983.4)	17 (2689.0)	-	0	0.1 (2)	0	-	0.4 (4)	0.1 (3)	0.2 (3)	-	0.7 (12)	0.1 (3)	0.3 (2)
SB	13 (779.0)	48 (6605.5)	19 (2901.0)	3 (276.0)	0	0.02 (1)	0	0	0	0.3 (17)	0	0	0	0.8 (33)	0	0
GF	0	6 (1350.0)	0	0	-	0	-	-	-	0.1 (2)	-	-	-	0	-	-
SG	1 (60.0)	297 (53748.0)	15 (1789.0)	15 (3460.0)	0	0.03 (11)	0	0	0	0.4 (57)	0.2 (4)	1.5 (52)	0	0.2 (30)	0.1 (1)	0.6 (8)
TF	0	0	0	2 (22500.0)	-	-	-	0	-	-	-	0	-	-	-	0
Qual.	5	46	21	11	-	-	-	-	-	-	-	-	-	-	-	-
Total	**19 (839.0)**	**439 (68703.5)**	**109 (10673.4)**	**50 (28925.0)**												
								ELECTROFISHING[d]								
EL	217 (40.8)	1319 (308.5)	909 (293.4)	441 (141.0)	0	0.76 (12)	1.0 (24)	1.5 (17)	0	1.0 (26)	0.6 (17)	1.2 (15)	0	0.1 (3)	0.1 (5)	0.1 (1)

[a]See Table 4-1 for gear codes.
[b]CPE = fish/100 ft/100 hr
[c]CPE = fish/100 hr
[d]CPE = fish/10 hr
[e]CPE = fish/100 m²
[f]CPE = fish/10 hr

Table 8. Arithmetic mean catch rate (AMcpe) of adult, juvenile and YOY rainbow trout by gear in the Colorado River in Grand Canyon, October 1990-November 1993.

GEAR[a]	Total samples (Total time - hr) REGION				AMcpe (number of fish) Adult RB REGION				Juvenile RB REGION				YOY RB REGION			
	0	I	II	III	0	I	II	III	0	I	II	III	0	I	II	III
NETS[b]																
GM	63 (134.4)	378 (791.8)	298 (604.8)	193 (414.1)	1.3 (2)	6.0 (39)	0.3 (2)	0	0	0	0	0	0	0	0	0
GP	56 (119.4)	477 (1006.0)	507 (1030.1)	281 (595.7)	54.0 (66)	38.0 (383)	5.0 (47)	0.8 (5)	0	0	0	0	0	0	0	0
GX	0	180 (374.1)	174 (368.0)	155 (318.5)	-	16.6 (51)	4.2 (13)	1.9 (6)	-	0.3 (1)	0	0.7 (2)	-	0	0	0
GZ	0	0	16 (31.4)	14 (27.2)	-	-	0	0	-	-	0	0	-	-	0	0
TK	174 (371.7)	989 (2060.0)	1263 (2634.9)	803 (1667.0)	79.7 (214)	22.6 (317)	8.3 (160)	1.5 (19)	0.8 (2)	0.1 (1)	0.1 (1)	0	0	0	0	0
TL	137 (295.6)	1044 (2165.1)	1386 (2876.3)	668 (1436.7)	101.7 (222)	47.0 (741)	3.4 (68)	1.3 (13)	0	0.1 (1)	0.1 (1)	0.1 (1)	0	0	0	0
TM	49 (110.7)	189 (393.0)	390 (803.3)	119 (243.3)	175.5 (107)	15.0 (27)	13.4 (49)	1.7 (2)	0	0	0	0	0	0	0	0
TN	43 (92.8)	175 (362.9)	410 (858.6)	139 (285.1)	173.1 (85)	42.3 (75)	4.4 (20)	0	0	0	0	0	0	0	0	0
TW	8 (15.7)	3 (6.1)	11 (21.5)	0	0	0	0	-	0	0	0	-	0	0	0	-
TY	0	6 (11.1)	0	0	-	82.0 (7)	-	-	-	0	-	-	-	0	-	-
TZ	0	3 (5.2)	0	0	-	0	-	-	-	0	-	-	-	0	-	-
Totals	**530 (1140.3)**	**3444 (7175.3)**	**4455 (9228.9)**	**2372 (4987.6)**												
TRAPS[c]																
HL	0	4 (37.1)	40 (687.5)	19 (316.1)	-	0	7.8 (39)	1.6 (5)	-	0	0.4 (3)	0.5 (2)	-	0	0	0
HM	0	2 (38.8)	13 (191.3)	2 (39.3)	-	0	15.8 (35)	0	-	0	5.7 (3)	0	-	0	0	0
HS	0	4 (30.8)	73 (1187.6)	9 (150.4)	-	0	9.8 (102)	0	-	0	1.3 (14)	0	-	0	0	0
MT	12 (210.3)	3847 (65866.7)	622 (12752.2)	81 (1721.2)	0	0	0	0	0	0.01 (6)	0.01 (2)	0	0	0.02 (7)	0.05 (8)	0

Totals	**12 (210.3)**	**3857 (65973.4)**	**748 (14818.6)**	**111 (2227.0)**												
								SEINES[e]								
		(area m²)														
SA	0	42 (7000.0)	54 (5983.4)	17 (2689.0)	-	0.02 (1)	0.02 (5)	0.1 (1)	-	0	0.1 (5)	0	-	0	2.3 (34)	0
SB	13 (779.0)	48 (6605.5)	19 (2901.0)	3 (276.0)	1.1 (2)	0.2 (5)	0.4 (6)	0	0.6 (6)	0.1 (5)	0.2 (6)	0	0	0	0	0
GF	0	6 (1350.0)	0	0	-	0.1 (1)	-	-	-	0	-	-	-	0	-	-
SG	1 (60.0)	297 (53748.0)	15 (1789.0)	15 (3460.0)	0	0.2 (67)	0	0	0	0.02 (7)	0.04 (2)	0	0	0.01 (1)	0	0
TF	0	0	0	2 (22500.0)	-	-	-	0	-	-	-	0	-	-	-	0
Qual	5	46	21	11	-	-	-	-	-	-	-	-	-	-	-	-
Total	**19 (839.0)**	**439 (68703.5)**	**109 (10673.4)**	**50 (28925.0)**												
								ELECTROFISHING[d]								
EL	217 (40.8)	1319 (308.5)	909 (293.4)	441 (141.0)	343.8 (1314)	123.1 (3423)	86.1 (1981)	4.4 (61)	88.3 (283)	14.3 (391)	12.9 (348)	3.7 (58)	9.7 (34)	1.9 (47)	0.9 (30)	0.3 (7)
								ANGLING								
AN	0	2 (1.7)	0	0	-	0	-	-	-	0	-	-	-	0	-	-
AL	0	4 (4.5)	0	0	-	216.7 (8)	-	-	-	0	-	-	-	0	-	-
Totals	**0**	**6 (6.2)**	**0**	**0**												

[a]See Table 4-1 for gear codes.
[b]CPE = fish/100 ft/100 hr
[c]CPE = fish/100 hr
[d]CPE = fish/10 hr
[e]CPE = fish/100 m²
[f]CPE = fish/10 hr

Table 21. Data and evaluation of condition for 34 radio-tagged adult humpback chub recaptured from the Colorado River in Grand Canyon, October 1990 - November 1993.

PIT Tag	Sex	Implant Release Date (ymd)	Recap Date (ymd)	# Days at large	RM Cap	RM Recap	Net Displac[1] (miles)	Original Weight (gm)	Recap Weight (gm)	Weight Change (%)	Surgical Procedure[2]	Condition[3]	
												Primary Incision	Antenna Exit
7F7F3F3626	F	901017	910112	87	60.4	61.4	-1.0	780	713	-67(8.6)	MGM	poor	poor
7F7F456B2C	M	901020	910116	88	65.5	64.7	+0.8	605	544	-61(10.0)	MGM	fair	poor
7F7F3C4162	M	901123	910114	52	64.4	64.1	+0.3	732	681	-51(7.0)	MGM	good	fair
7F7F3F4E77	M	901117	910311	114	61.0	61.2	-0.2	675	649	-26(4.0)	MGM	fair	fair
7F7F3F520D	M	910311	910515	65	61.2	60.9	+0.3	604	565	-39(6.5)	MGM	good	fair
7F7F3C243E	M	910311	910612	93	61.2	60.9	+0.3	580	514	-66(11.0)	MGM	poor	poor
7F7F3E2F3A	F	901019	910708	169	64.6	127.0	-61.5	500	452	-52(9.2)	MGM	good	fair
7F7F3C6F15	M	910518	910914	119	61.4	64.7	-3.3	554	555	+1.0(0.2)	MGM	good	fair
7F7D075B05	F	910612	911110	151	60.2	60.8	-0.6	644	594	-50(8.0)	MMM	poor	fair
7F7F3E3C5C[4]	F	901118	910725	256	61.1	2.9km[5]	-2.1	798	494	-304(38)	MGM	no photo	no photo
7F7F3E3C5C	F	901118	911110	357	61.1	61.3	-0.2	798	572	-226(28.0)	MGM	good	fair
7F7F3E3C5C[4]	F	901118	930512	906	61.1	5.91km[5]	-3.9	798	565	-233(29.2)	MGM	good	good
7F7F3E3C5C	F	901118	930715	969	61.1	61.2	-0.1	798	619	-179(22.4)	MGM	good	good
7F7F3F3764	F	910914	911112	59	64.7	64.6	+0.1	639	604	-35(5.5)	LMS	good	good
7F7F3E3542	M	910915	911113	59	64.4	64.4	0.0	612	580	-32(5.0)	LMS	good	good
7F7D086032	F	910613	920113	214	61.1	60.7	+0.4	669	686	+17(2.5)	MMM	good	fair
7F7F475E72	M	920308	920410	33	61.5	61.5	0	633	591	-42(6.6)	MMS	good	good
7F7F475E72[4]	F	920308	920424	46	61.5	0.9km[5]	+0.7	633	561	-72(11.4)	MMS	good	good
7F7D140108	M	920114	920509	116	60.7	61.5	-0.8	728	655	-73(10.0)	LMS	good	good
7F7F321C62	M	920713	920912	61	61.2	60.2	+1.0	628	660	+32(5.1)	LMS	good	good
7F7F1F6A79	F	911109	930115	431	60.1	61.2	-1.1	605	647	+42(6.9)	MMS	good	good
7F7D4D7901[4]	F	-	930117			63.8	-	-	591	-	M--	good	good
7F7D073D4A	M	930319	930521	63	127.5	127.6	-0.1	874	854	-20(2.3)	MMS	good	good
7F7D073D4A	F	930319	930619	92	127.5	127.5	0	874	844	-30(3.4)	MMS	good	good
7F7F21741B[4]	M	911112	920330	139	64.8	0.9km[5]	+4.0	557	505	-52(9.3)	LMS	good	good
7F7F1E7A65[4]	F	920408	920623	76	61.75			843	721	-122(14.5)	LMS	good	good

7F7E4B1037[4]	F	920111	-		58.3			556	-	-	LMS	good	good
[4]	F	-	910616			0.4km[5]			405	-		poor	fair
7F7F3C303B[4]	F	901116	910331	136	60.1	0.0km[5]	-1.25	665	554	-111(16.7)	MGM	good	good
7F7D084C05[4]	F	910715	920424	284	59.9	3.65km[5]	-3.7	566	557	-9(1.6)	MMS	good	good
7F7E432514[4]	F	920113	920427	105	60.4 5	1.0km[5]	-1.5	959	765	-194(20.2)	MMS	good	poor
7F7F456D61[4]	F	911107	930512	548	58.8	5.91km[5]	-6.2	710	625	-85(12)	MMS	good	good
7F7F206B7B[4]	F	920909	930613	277	58.2	0.0km[5]	-3.1	760	509	-251(33.0)	MMS	good	good
Not Recorded[4]			930424			3.07km[5]			563			no photo	no photo

[1] (+) = upstream, (-) = downstream

[2] MGM = midline incision, CV3 Gortex nonabsorbable sutures, no needle guide.
MMM = midline incision, 3-0 Maxon absorbable sutures, no needle guide.
MMS = midline incision, 3-0 Maxon absorbable sutures, with SNAG needle guide.
LMS = lateral incision, 3-0 Maxon absorbable sutures, with SNAG needle guide.

[3]-good - slight or no inflammation - healed/healing
fair - moderate inflammation/mild infection
poor - dehiscent incision or exit - infection present

[4] Recaptured by AGF or ASU

[5] recaptured in LCR